DEPRESSION IN '47?
...controls can bring one

IT IS CONVENTIONAL for the American business man, who values freedom, to protest against government regulation. On this account, many people who do not know the facts in detail are inclined to discount current business protests against the post-war application of wartime economic controls. This is particularly true since in his report for the third quarter of this year, the Director of War Mobilization and Reconversion implied that business is in fine health by remarking that "business profits, after taxes, are at the highest point in history."

In complaining about government controls, however, the American business man is not crying wolf. These controls were an essential war weapon. Now, however, they are contributing decidedly to a twisting and distorting of the American economy in a degree which, if not soon corrected, may well start production and employment down the toboggan.

One general indication of how badly twisted our economic system has become is found in the wide disparities in the amounts by which different groups of prices have increased. Since 1941, for example, farm prices have advanced an average of about 125%. Industrial prices, more tightly controlled than any other group except rents, have increased only about 32%. Meanwhile, straight time hourly earnings of industrial workers have gone up about 60% and the cost of living about 43%.

The advances of individual prices within these groups have also varied enormously. Among industrial prices, that of finished steel has gone up only about 14% since 1941, while lumber has gone up over 50%. Hourly wage rates in the women's garment industry have gone up 116%, while those in the brewing industry have gone up only 33%. That share of the cost of living due to rent has gone up only 4%, while that due to the cost of clothing has gone up over 60%.

Well, What Of It?

At least four things of major importance:

1. Production, under the influence of price control, has been heavily concentrated in some lines to the neglect of others. Result—unbalanced production, unbalanced inventories, and a serious cut in the flow of goods to consumers.

2. More or less uniform post V-J Day wage increases, promoted by the federal government, have imposed a far more serious cost problem on some industries than on others. This is particularly true of some of the most basic industries.

3. While, as a whole, "business profits, after taxes, are at the highest point in history" (due in part to a temporary excess profit tax rebate arrangement) there are enormous disparities in the profits of different industries. Some key industries are making little or no profits.

4. **If not corrected, the distortion of prices, wages and production, which has resulted in such a wide disparity of profits, can contribute decisively to a major business upset.**

The most striking example of the distortion of production by controls was, of course, that provided by a metropolitan meat famine at a time when beef cattle crowded the ranges. This has now been recognized. But there are many other distortions. Abundance of sports clothes, acute shortage of more essential clothing made from the same kind of cloth. Successive shortages of critically important products like baling wire and nails as the price lid on steel is jiggled first this direction and then that.

Some of these distortions of production are due to material shortages. But a major contributor is uneven application of controls, and the total removal of some while others are held firm. Among the results are bulging inventories of partially completed assemblies and shut-downs while waiting for parts.

Wage Complications

While price controls, unevenly applied, have shunted production first this way and then that, the federal government has further complicated the situation by promoting uniform wage rate increases without regard to varying capacities to pay them. The greatest single contribution to this distortion was made by the President himself. In the course of

unsuccessfully trying to mediate the dispute over steel wages last January he recommended a wage rate increase of 18½ cents an hour. Immediately that increase was accepted by organized labor as par for the first round of wage adjustments, having the sanction of the White House itself. The game then became to beat par.

But the capacity of different industries to pay wage increases varied greatly. During the war some had hiked their pay much more than others. Moreover, in some industries wages are a much larger element of total cost than in others. In 1939 (last year for which figures are available) wages ranged all the way from 2½% of total sales in cigarette manufacturing to 34.3% in hosiery manufacturing and 65.2% (for wages and salaries combined) in soft coal mining.

Under these circumstances, some industries were far less able to meet a uniform wage increase than others. Nonetheless, many of them had uniform wage increases imposed upon them. Then the price lid was held firm. This, coupled with material shortages and production difficulties which also choked output, squeezed the profit right out of those industries.

A Study In Contrasts

Some of the most important industries are making little or no profits while they bump along on a production volume which fails to meet consumer needs and prevents attainment of maximum efficiency. The automobile industry affords one conspicuous example. Another is electrical manufacturing, and rail equipment is yet a third. All of them are crucially important. Many other lines of business, of course, are extremely profitable. For example, the profits of a group of large retail stores were 150% higher during the first half of this year than they were a year ago; the profits of a group of motion picture companies were up 140%.

In the meantime, the workers in some of those low-profit industries are in no bed of roses. The increase in the cost of living since 1941 is now outstripping the increase in the hourly wage rate of workers in a number of industries, where wage rates have not risen as much as the average. On a weekly basis, a shorter work week, with less overtime, has combined with the recent upsurge in consumer prices, to place the living standards of some of these workers below the wartime level.

Such circumstances obviously create pressure in the ranks of these workers for another round of wage increases. But as long as the profit remains squeezed out of their industries wage increases, if any, must be translated either into higher prices, or, if the government sits tight on the price lid, into losses which will discourage production and ultimately cost workers their jobs.

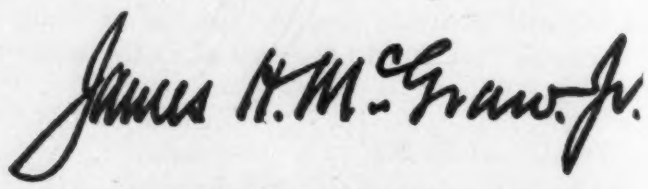
What To Do?

Salvation both for the workers and for employers in the relatively profitless section, a peculiarly important group of industries, must be looked for primarily by increasing productivity, thereby decreasing the cost per unit. Part of this higher productivity can come only from individual efforts of the workers themselves. Another part can come from an elimination of bottlenecks in materials and parts which prevent the labor force from working most efficiently. Only by greater output per man-hour can workers and management solve their common problem.

Until productivity has been thus increased, it is hard to think how the federal government could do a greater disservice both to labor and to industry than to repeat its performance of promoting a uniform national wage increase. With the present distortion of the national economy, some industries might again take such an advance in their stride. With many others it would raise even greater havoc.

While avoiding like the plague promotion of another uniform wage adjustment, the federal government must make it a primary objective to relieve distortions caused by the uneven application of other controls, primarily price control. Nature has given a lift to the elimination of distortions by providing bumper grain crops which should in time reduce that staggering disparity between a 125% increase in farm prices and a 32% increase in industrial prices. But that process must be speeded as a matter of conscious policy. No element of such a policy is more important than expediting the decontrol of industrial prices. Such a course is clearly essential to achieve that balance in the production of materials and parts required for maximum output.

Business and labor both want a sustained prosperity in which all will share. Sustained prosperity can be achieved only if we eliminate the distortions in wages, prices and profits which now restrain so much vital production.



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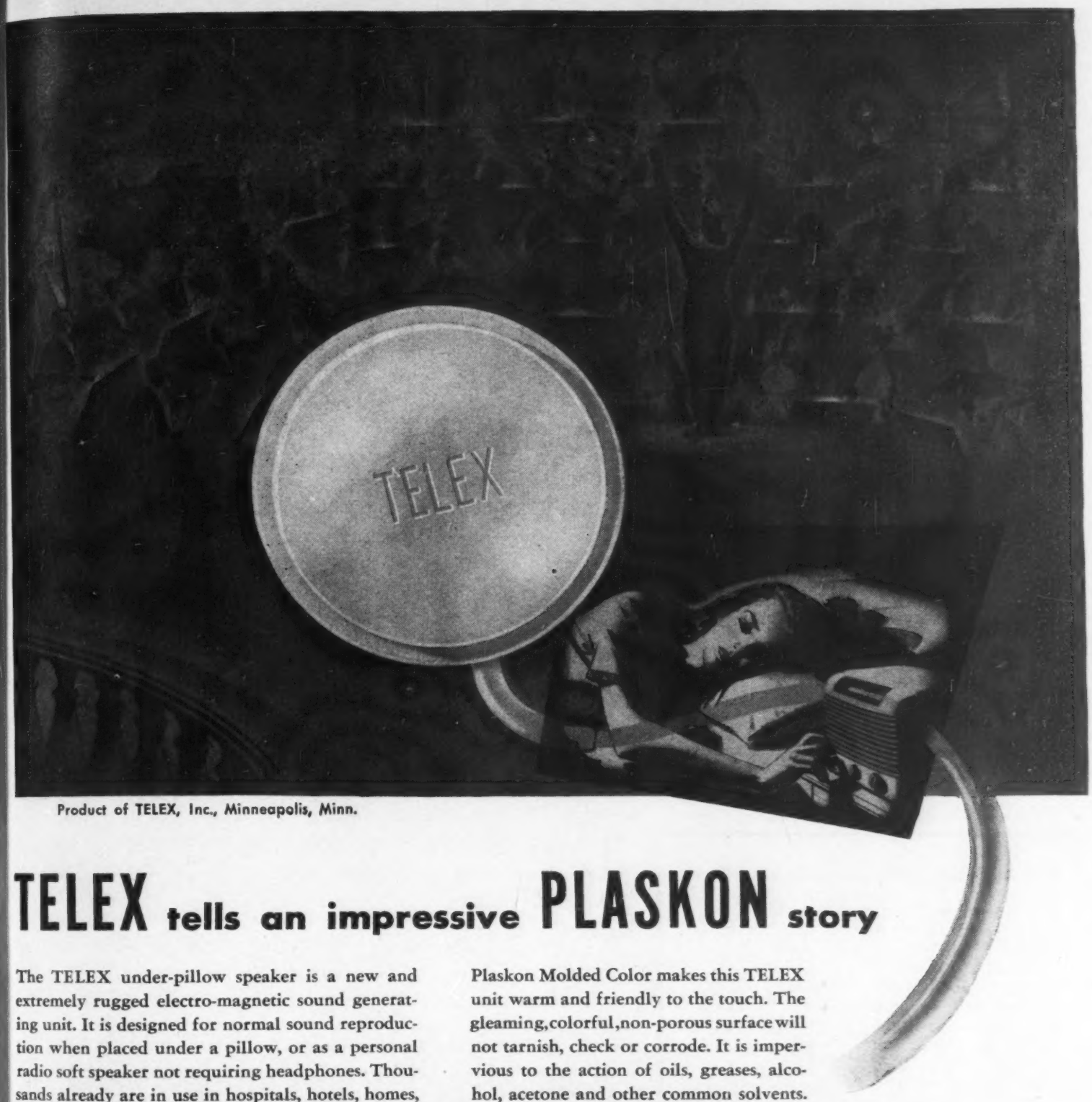

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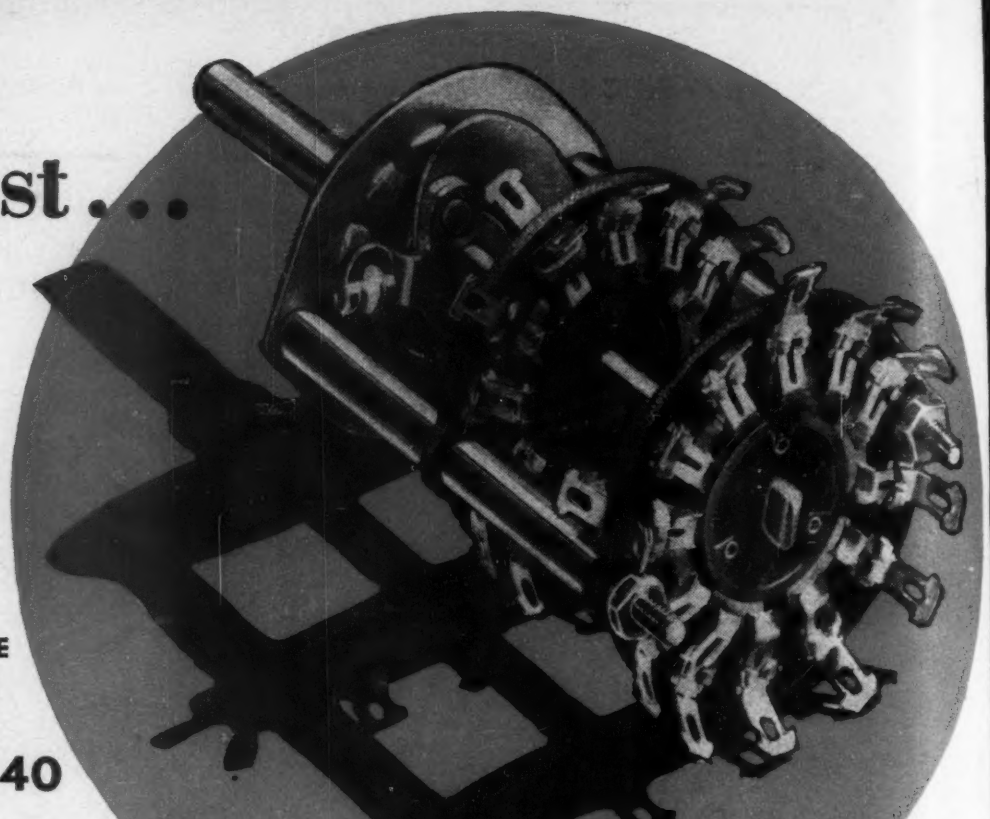

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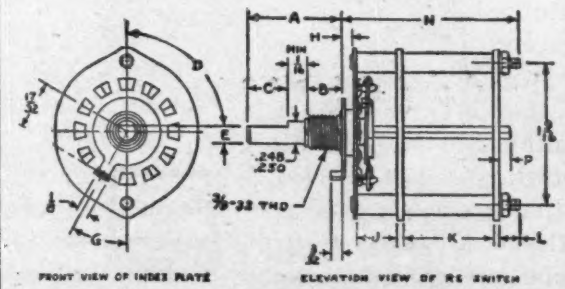

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CROSS TALK

▶**D. G. F. . .** As part of a plan conceived before the war and delayed in coming to proper fruition because of the war, Donald G. Fink becomes Editor of ELECTRONICS on November 15.

Mr. Fink came to the editorial staff in 1934 from MIT where, after graduation in communication engineering, he had put in a year of research in the departments of geology and electrical engineering. During the succeeding years he became Associate and then Managing Editor. Loaned to the Radiation Laboratory shortly after its formation, he had much to do with the development of loran and the location of stations in the European and Asiatic war theaters. In the office of the Secretary of War under E. L. Bowles his electronic background was put to good use in the development of electronic aids to aviation. Returning to the staff late in 1945 as Executive Editor, he was soon asked by the Navy to go to Bikini on a special job, coming back to this country in September of this year after a four-months jaunt into the Pacific.

During Mr. Fink's years on the staff his interest in television resulted in the design and construction of receivers later described in ELECTRONICS, in service with the National Television Systems Committee, and later with the Radio Technical Planning Board. Two of his four books, "Principles of Television Engineering" and "Television Standards and Practice," stemmed from this interest.

Mr. Fink's taking over the full responsibility for directing the editorial activities of ELECTRONICS relieves the present editor of that more-than-full time job, a prospect which alternately looked bright and then dark as the vagaries of the war dictated.

After 16 years on the job, the present editor looks with much favor upon younger shoulders taking on the task of seeing that the magazine is, as always, at the top in its service to the technical side of a young and vigorous industry. He is happy to be able to continue with it as Consulting Editor, maintaining his office with the staff and continuing the many friendships which nearly twenty-five years of technical publishing have formed. In addition, there are certain jobs which can be undertaken only by a man free from direct daily responsibility for the operation of the paper. From time to time the results of such activities will find their way into the editorial pages.

▶**CODE . . .** Rummaging around the editorial office recently, on a clean-up campaign, the first book in which manuscript records were kept was found. The first entry, dated June 1, 1931, was for a manuscript entitled Super-Midget Radio Transmitter, by James A. Code, Jr., Captain, U. S. Army. Not long ago the author of this article retired from the army after a distinguished career, most recently as Assistant Chief Signal Officer. Major General Code is now vice president of the Automatic Electric Company, Chicago, where he is playing a new, but none the less important, role in the communications business.

In a recent letter to the editor, General Code expressed very clearly the importance of maintaining the spirit — as well as the funds — for research in our military and naval departments:—

"Most of our military and naval expenditures in time of peace are like fire insurance premiums — we hope that we may never need to get any benefit from them. Funds put into research and development form one outstanding exception to this rule; they pay dividends in peace or war, and without regard to the military objectives of the projects to which the funds are applied; one might almost say in spite of those objectives. For military and civilian engineering are so closely allied that one cannot advance without pulling the other with it. The military side automatically falls heir to civilian advances. It, therefore, applies its funds to projects which seem to have no civilian application, or where the goal seems so remote that commercial companies cannot take the risks involved. That was the way the Signal Corps got its first operating radar equipment in 1937, when the commercial companies did not want to touch the project, yet the civilian byproducts alone have more than justified every cent of the cost. That is the way it will always be. That is why, whatever else we do to our military and naval establishment, we must not skimp their development funds, for those funds pay dividends in money, in security, and in human lives."

ELECTRONICS AT BIKINI

Telemetering, radio and radar monitoring, television and stratovision measured effects of atomic bombs, while 3,800 electronic equipments were exposed on target ships. First published details of Crossroads electronics program

By DONALD G. FINK
Executive Editor, Electronics

and

CAPT. CHRISTIAN L. ENGLEMAN, U.S.N.
Electronics Coordinating Officer Joint Task Force One

TABLE I

Electronic Equipment Exposed to the Bikini Bombs

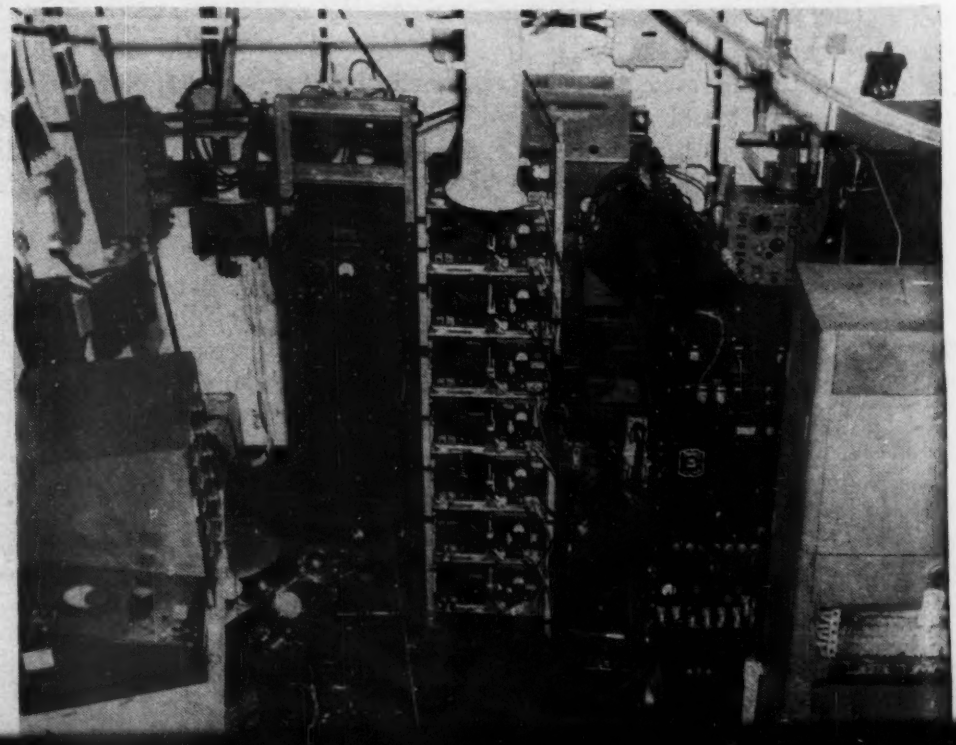
Type	*Test Able*	*Test Baker*
Fire-control radars	48	46
Surface-search radars	66	64
Air-search and airborne radars	85	68
Radar repeaters	100	97
Radar countermeasures equipment	36	36
Radar and radio beacons	7	7
IFF equipment	277	237
Radio transmitters	251	222
Radio receivers	813	720
Antennas	10	10
Radio transmitter - receivers	498	525
Sonar echo-ranging equipment	40	40
Sonar echo-sounding equipment	78	61
Loran navigation equipment	37	36
Communications auxiliary equipment	1069	1013
Teletype equipment	5	—
Test equipment	288	274
Telephone, intercommunication	123	70
Radio direction-finding equipment	4	3
Total	3835	3529

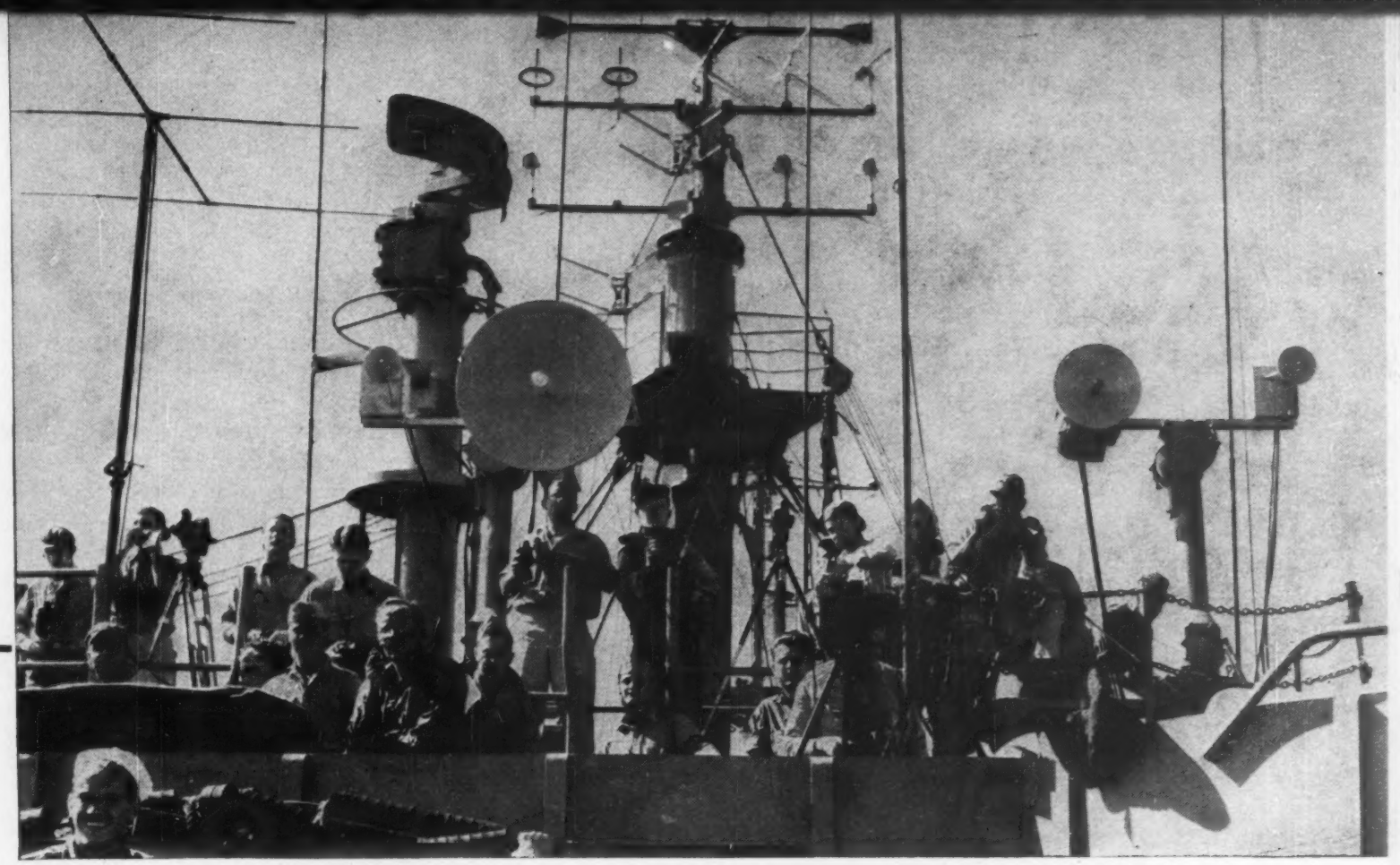
THE PURPOSE of the electronic program of Operation Crossroads was twofold: (1) to expose electronic equipment of the Navy and the Army to the effects of atomic bombs and to assess the damage, and (2) to provide electronic systems for measuring and observing the technical effects associated with bomb explosions, such as water and air pressures, radio wave propagation, wave heights and the like.

To implement this program, the Electronics Coordinating Officer was appointed to organize and direct the work. A staff of 85 officers, 75 civilians and 300 enlisted men was assembled, all electronic specialists. The civilians were recruited from the Naval Research Laboratory, the Signal Corps Engineering Laboratory, and from 13 industrial and academic laboratories. This group was charged with all the electronic activity of the task force, except the airborne drone control equipment and the Manhattan District bomb-detonating and timing-signal systems.

The base of operations of the Electronics Coordinating Officer (ECO) and his staff was the USS Avery Island, a 10,000-ton Liberty-type hull converted for use as an electronic supply and repair ship. This ship was remodeled to provide air-conditioned laboratory spaces and quarters for the staff, and a number of specialized antenna structures covering the frequency range from 7 mc to 26,000 mc were installed topside.

Telemetering receivers (center) for recording pressure-time pulse of underwater burst. High-speed camera (right) records at the rate of 600 inches of 35-mm film per second





All set for the Baker Blast. Technical personnel aboard radar platform of USS Avery Island, a few minutes before the second atomic explosion. Note radar monitoring dishes, and intercept antennas on mast (top center)

The basic job of the ECO was to determine what happened to standard military electronic equipment when exposed to the air burst and underwater burst of the atomic bombs. The target ships numbered 75 in Test Able (air burst) and 73 in Test Baker (underwater burst). All of the electronic equipment normally installed on these ships, including radio transmitters and receivers, radar, sonar, loran, public address and communicating equipment, was examined prior to each test and its condition recorded.

Exposure and Inspection of Equipment

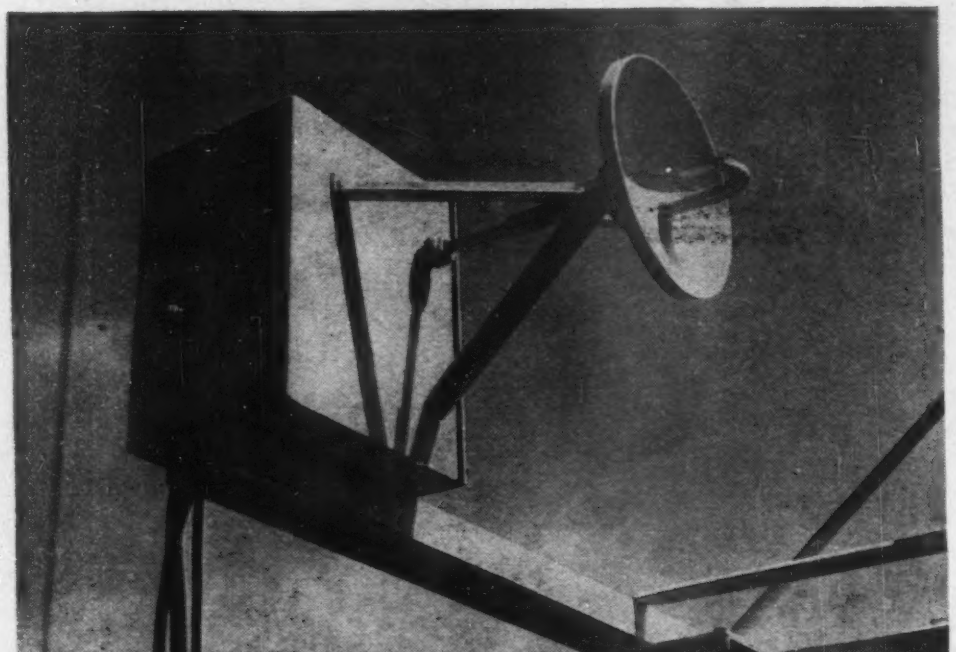
Prior to Test Able, 97 percent of all the equipment was found to be in operating condition. In addition to shipborne equipment, electronic equipments of the Naval air arm, and of the Army Ground Forces, were exposed on the decks of various vessels and on Bikini Island. In all, this array of equipment numbered 3,835 different items in Test Able, 3,529 items in Test Baker. Table I shows the breakdown of exposed equipment by types.

Some idea of the scope of the damage inspection job can be gathered from the fact that over 800 communications-type receivers were exposed, the radar equipment numbered nearly 300 major items, test equipment over 250 major items, and even specialized items like sonar and loran numbered approximately 50 major items of each type.

Following each blast the target equipment was inspected, at first visually and later, when power was available, by thoroughgoing application of test equipment. This job took a force of 150 specialists several weeks following each blast. The condition of each equipment following each blast was recorded in tabular form, requiring a report of 1,060 pages for the Able test alone.

Details of the damage caused to electronic equipment have been classified "secret" by the Joint Chiefs of Staff and hence cannot be revealed. The distance relative to the bomb within which equipment suffers severe damage, not repairable at sea, the additional distance within which minor damage is sus-

Permanent records of signals were made by photographing cathode-ray screens. Here is set-up for measuring infra-red radiation from blast



K-band (one centimeter) dish for monitoring APS-34 radar transmissions through blast cloud. Note curved waveguide feed

tained, and the distance beyond which the damage is negligible, are known. Thus, the damage-inspection function of Operation Crossroads was successfully accomplished. General conclusions have been drawn, the weak points of particular equipments revealed, and this information is being forwarded to equipment designers in the Naval Bureaus and the Signal Corps.

Electronic Instrumentation

While the primary purpose of the Bikini tests was to assess damage produced by the bomb at various distances, it was not sufficient merely to expose the equipment and examine it afterwards. This procedure would reveal *what* had happened, but would leave largely unanswered the question of *how* the damage was caused. This "how" factor involved the values of pressure, temperature, blast and shock to which the equipment was subjected. Without such quantitative information, designers would find it difficult to improve the designs found inadequate. To permit interpretation of observed damage, a program of scientific instrumentation was set up.

In the field of electronics, this instrumentation program had five major parts: (1) television for direct observation of the blast and its effects, and for measuring the heights of waves; (2) a study of electromagnetic wave effects, including monitoring of radio and radar equipments operating during each blast, these being on ships and on one of the Bikini islands; (3) telemetering of air and water pressures created by the explosions; (4) telemetering of radioactivity, and (5) precise measurement of the relative timing of various events connected with the explosion.

The Television System

Two light-weight television transmitting systems (type ARK/ATK or "Block III") were set up on Bikini Island, about three miles from the blast center. These equipments weigh only 100 pounds, have a power output of 10 to 15 watts in the frequency range 150 to 270 mc, and produce a 350-line 40-frame picture using a standard iconoscope camera. The equipment was mounted atop 75-foot steel towers and so positioned that one camera viewed the target fleet, taking in about 10 of the principal target ships at the center of each array, while the other was trained on the nearby beach to televise waves caused by the exposions. Approximately 20 receivers were distributed among seven observing ships, including Admiral Blandy's flagship, the press ship, two official observer ships (military, scientific and United Nations observers), and three "working" instrumentation ships. The receivers employ 7-inch, green-phosphor cathode-ray tubes, and can tune to any of ten 8-mc channels separated 12 mc. Each receiver was fitted with one or more monitor picture tubes located at various points in each ship to permit as many as 100 observers to

The radio and radar monitor room. These men, from Naval Research Laboratory, were busy with equipment shown and did not see Able blast

view the scene simultaneously.

One of the problems of televising the air burst was the intense light generated by the atomic fission. Advance information stated that at the three-mile distance, bomb brightness would equal or exceed that of the sun for a period of several seconds. Since it was known that direct exposure to such light would burn the mosaic of the iconoscopes, tests were conducted at Bikini to determine the density of the optical filters necessary to protect the cameras. It was found that 100 percent modulation of the television carrier occurred when a camera viewed the sun through a filter of density 2.1 (transmission 0.008). It was also found that an illumination several hundred times that of the sun could be safely handled for a period of a few thousandths of a second. This was proved by exploding a four-million lumen flash bulb directly in front of the lens at a distance of one foot and noting the effect on the video waveform.

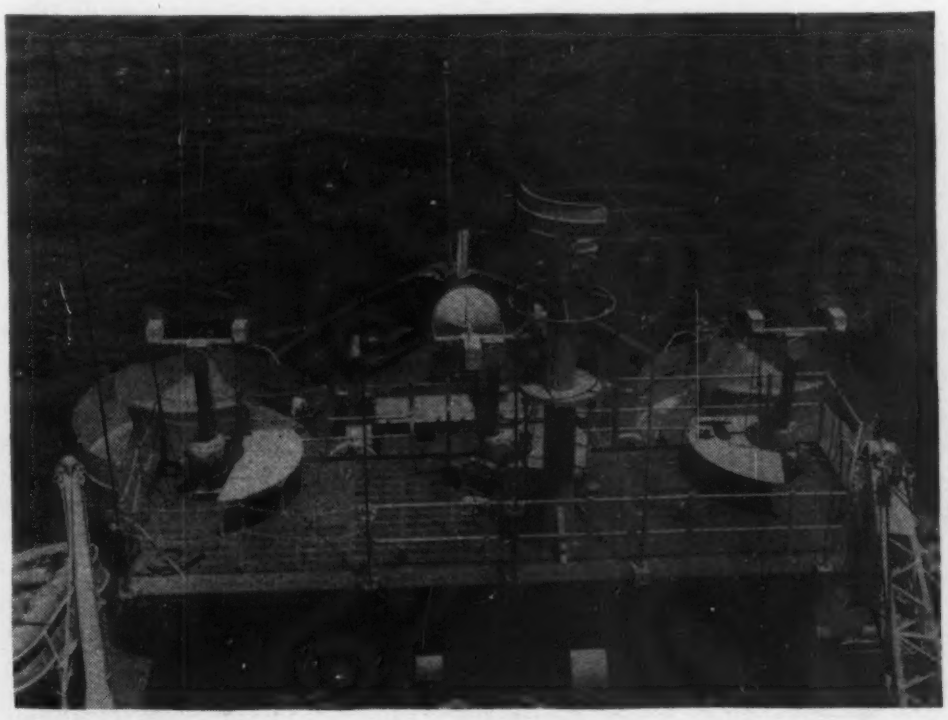
To protect the camera which viewed the air burst directly, a magnetically operated solenoid carrying a neutral-density filter of density 2.4 was positioned in front of the lens and controlled by a timing circuit having a delay of 13 seconds. The filter was positioned by a radio timing signal, scheduled for 5 seconds before the blast, and removed 8 seconds after the blast.

For reasons of safety and security, several of the observing ships were stationed at about 20 miles from the air blast. This exceeded the range of the 10-watt carrier, since the transmitter and receiver antennas were no more than 75 feet above ground. Accordingly, it was decided to operate an airborne television relay on the stratovision principle. Transmitting equipment identical to that on Bikini Island was installed on two PBM Mariner flying boats. Standard Block III receivers, which had been installed in the aircraft to permit motion-picture photography of the television scenes, were connected to the transmitters. The frequency separation between received signal and relayed signal was 24 mc, sufficient to avoid feedback difficulties. Excellent reception at the 20-mile range was achieved by this method, and recognizable pictures could be seen at 45 miles. During the Baker test, the ships were located at 10 to 12 miles, and the relay proved unnecessary when three-element directive arrays were installed on the Bikini transmitters.

One of the outstanding aspects of the television project was the reliability of unattended transmitter operation. In each test the transmitters were turned on about 2:00 am, and the camera circuits adjusted without an image, since darkness prevailed. Thereafter the transmitters continued to function without interruption, and without failure of any kind, surviving the effects of the blast and continuing to operate until turned off some 15 hours later. The images, while not of broadcast quality, were entirely adequate for the purpose and gave observers the first indication of the extent of the damage. The waves were of negligible height at the Bikini shore following the air burst, but were 5 to 10 feet high following the underwater test.

Don Fink, Executive Editor of *Electronics*, makes wire recording just prior to Able Day blast. Goggles reduced glare of blast by more than 10,000 times

"Black boxes", the battery-operated radio receivers, selective filters and relays which turned on equipment automatically just prior to each Bikini blast. Several hundred of these units were spread over target ships, observing ships, and islands



Bow of the USS Avery Island, showing radar platform from rear. Vertical whip antennas were used to monitor c-w transmissions on 5 to 15-mc from target ships

Radio and Radar Monitoring

The monitoring of radio and radar equipment had two purposes:

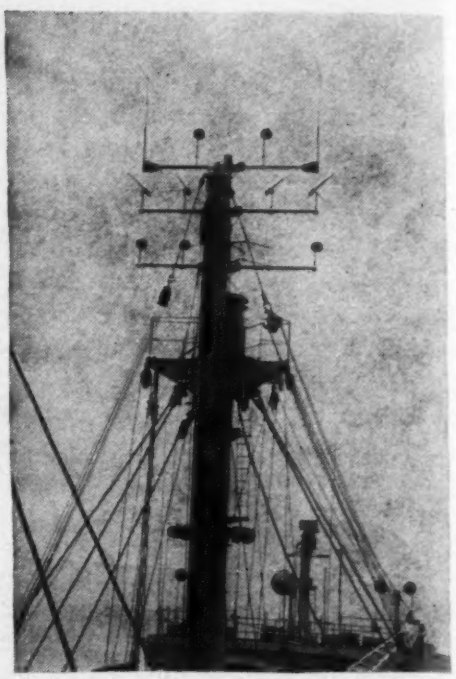
One was to observe the effects of the blast on the frequency, power output, pulse rate and pulse width of various radio and radar transmitters which were operating at the time of the blast on the target ships. The second was to observe what effects the blast cloud and its associated phenomena would have on radio wave propagation at various frequencies, particularly attenuation, generation of noise and atmospheric disturbances, and radar reflections from the target array.

For this purpose a large number of receivers and antennas were set up on the USS Avery Island and on Aomoen Island (one of the Bikini group) to record radio signals. Recording milliammeters and oscilloscopes photographed by motion-picture cameras were used to preserve the records. The frequency range covered the 5 to 15 mc short-wave communication band, the 200-mc range used by low-frequency radar and iff equipment, and the 10, 3, and 1-cm microwave radar bands. These equipments were successful in recording a number of interesting effects, details of which are still classified. In general it may be stated that an atomic explosion constitutes no serious bar to the employment of radio waves in the near vicinity.

Two 3-cm radar equipments on Aomoen Island produced records of the disposition of the target array before, during and after each explosion. These records are of value in placing the time at which various ships sank, at times when smoke and spray prevented conventional photography.

Elaborate arrangements were made to observe the blast cloud by radar at various distances. This was successfully achieved, although the distances and other pertinent details cannot be published. Records were also made of the "spherics" disturbances (natural static) present on the 0 to 5-mc range before, during, and after the blast in the Bikini area and at remote locations in Wake and Guam. The transmissions of standard Navy c-w transmitters, with keys tied down during the blasts, were monitored at Naval, FCC and other government monitoring stations.

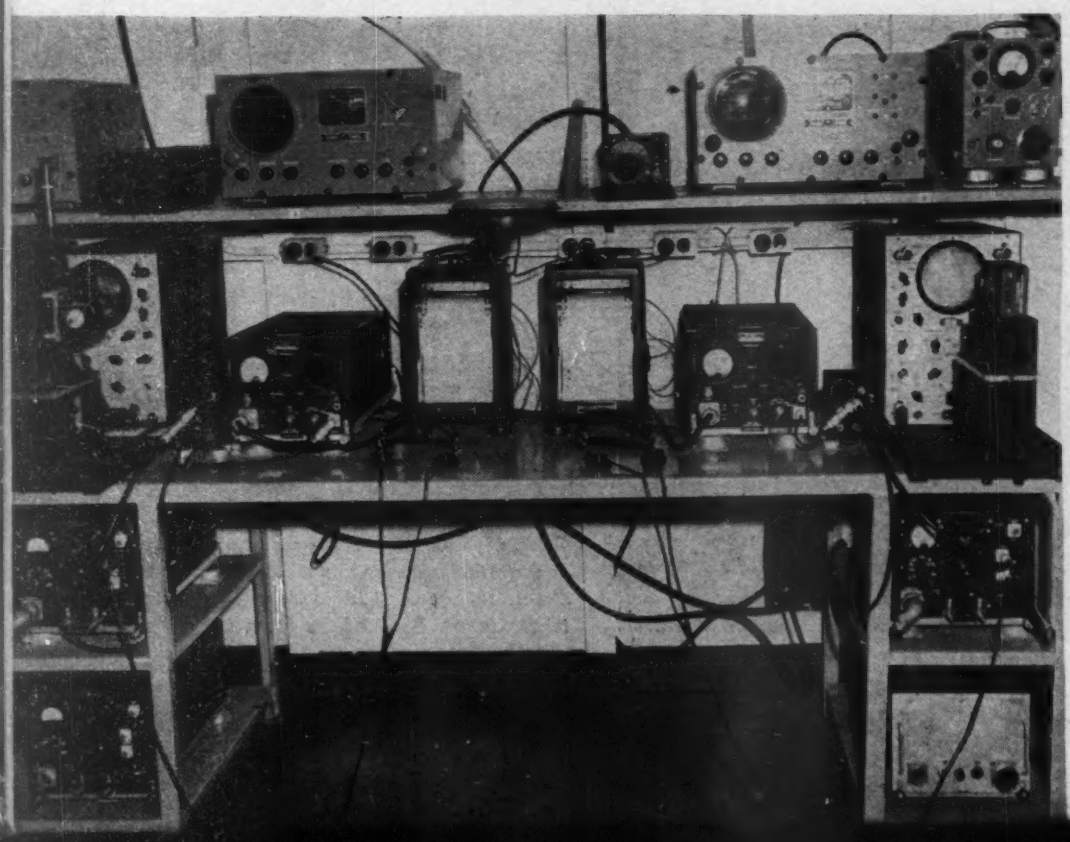
To measure air and water pressures created by the explosions as a function of time at various positions, it was necessary to set up several remote measuring systems. One of these telemetering systems used pressure gauges mounted on the superstructures and hulls of selected target vessels. The output of these gauges modulated 600-watt 70-mc frequency-modulation transmitters. In the air burst, 18 gauges were attached to a single transmitter which was connected to each gauge in turn (time sequence telemetering). In the underwater test, the rate of rise of pressure was much greater and the full bandwidth of the system was used to transmit the pressure pulse from a single gauge, five gauges and transmitters being used in all. Receivers located on the USS Avery Island reproduced the pressure-time pulse, which was recorded by a moving-coil oscillograph on paper tape in the case of the air burst, and by a high-speed cathode-ray oscilloscope on motion picture film in the underwater burst.



Weird collection of antennas on mast includes vertical 70-mc array for telemetering, seven intercept antennas with ground planes for 100-200 mc, and a corner reflector for television reception

A similar record of pressure in air and water was obtained by a string of 15 sonobuoys, (water-borne, battery-operated transmitters) arranged along a radial line from the target center at intervals of 100 feet. Microphones and hydrophones, when actuated by the blast, modulated the corresponding transmitter, which in turn actuated receivers on Aomoen Island some seven miles distant. A 15-element moving-coil oscillograph recorded the signals as functions of time on a photographic paper tape. This and similar photographic records were removed from Aomoen Island

Monitoring equipment and recorders. The photograph shows just a small portion of the gear used to cover all frequencies from 5 mc to 26,000 mc. during the Able blast. Oscillographic cameras (left and right) and recording milliammeters (center) made permanent records



after the Baker test by helicopter, since the radioactivity was too intense to permit approaching the island by boat. Film records of the radar images were fogged by radioactivity and might have been completely ruined if allowed to remain until the radioactivity had subsided.

Still another telemetering system was used to transmit radioactivity levels from the target vessels after the Baker test. Geiger-counters and ionization gauges were connected to standard Signal Corps SCR-694 battery-operated transmitters, so connected that each pulse of the detector caused a break in the carrier. The outputs of receivers on the USS Avery Island were connected to recording milliammeters which recorded the intensity for a period of several days after the explosion. The radio-activity was intense. A continuous plot was kept. From the various rates of decay observed, it was possible to predict long before the vessels were boarded that they would remain uninhabitable for many weeks if not months. Even at the present writing, more than two months later, many of the vessels can be boarded safely only for brief periods.

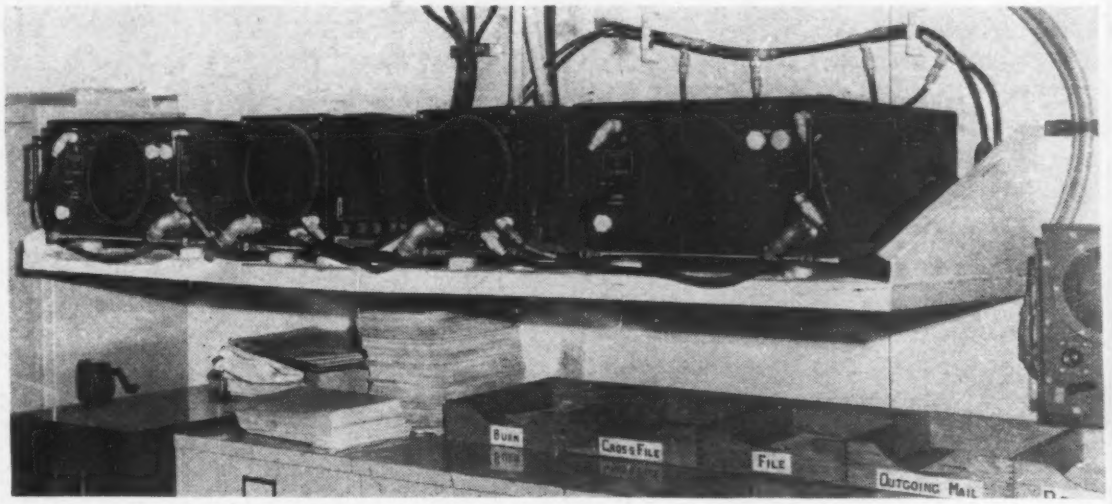
Remote control was used to guide drone boats in and out of the contaminated area, to pick up water samples as a further aid in determining radioactivity levels, and to aid in computing the efficiency of the atomic bomb. This equipment, adapted from remote control equipment developed during the war, permitted the motor to be started, the anchor slipped, the throttle advanced or retarded, and the rudder turned left, right or centered, and operated a pump for collecting water samples, all by pushbutton control from a vessel outside the lagoon. Airborne observers guided the controllers, by radioing instructions to the control ship. This equipment operated successfully and permitted observation long before human beings could approach the contaminated area.

More conventional electronic equipment in the form of a 50-watt broadcast transmitter was operated by the ECO for the entertainment of the Task Force. Wire recorders were also used to preserve running accounts of the activity aboard the ship during both tests.

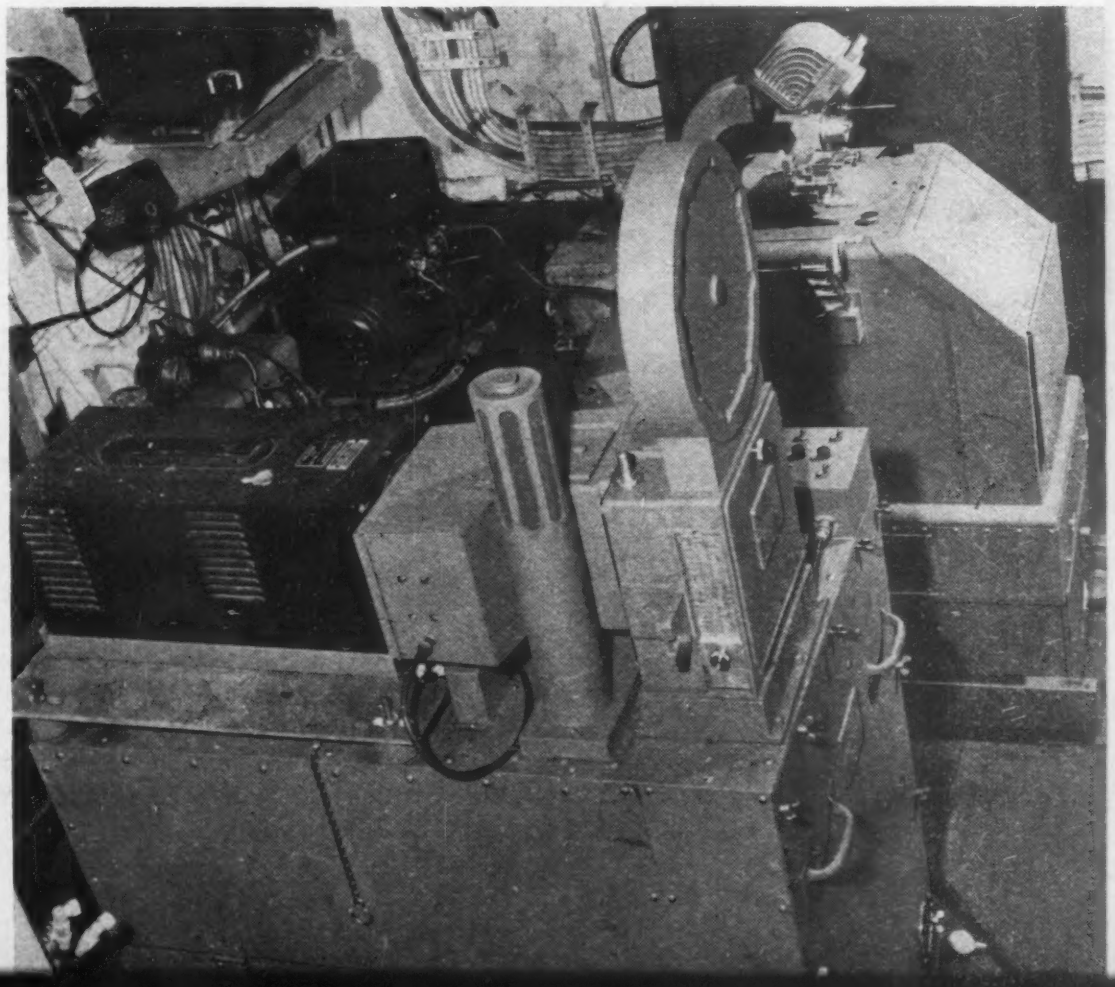
The many electronic equipments involved were set in motion just prior to the blast by audio timing signals sent by radio from the USS Cumberland Sound, the laboratory ship of the Manhattan District. These were received by battery-operated receivers, fitted with selecting filters and relays to actuate equipment at internals from two minutes to two seconds prior to each blast. As a check on the operation of these devices, in the Baker test a time-monitoring system was set up which related the time signals, and the actual detonation, with world time, by comparison with WWV signals.

All of this complicated electronic equipment operated satisfactorily, with a few exceptions traceable to human error or to the fact that the delicate equipment aboard the target ships was put out of action by failure of power supply or by the blast itself. Interpretation of the results and correlation with observed damage are now underway.

Battery of two television receivers and associated monitors, mounted in "office" of electronics laboratory ship. Additional monitors were provided in lounge and on bridge



The Hobart camera, which took still pictures from television picture tube (in black case at left), at rate of one per second, processed them automatically, and projected positive image on screen (at right) two minutes later



Wideband Microwave Amplifier Tube

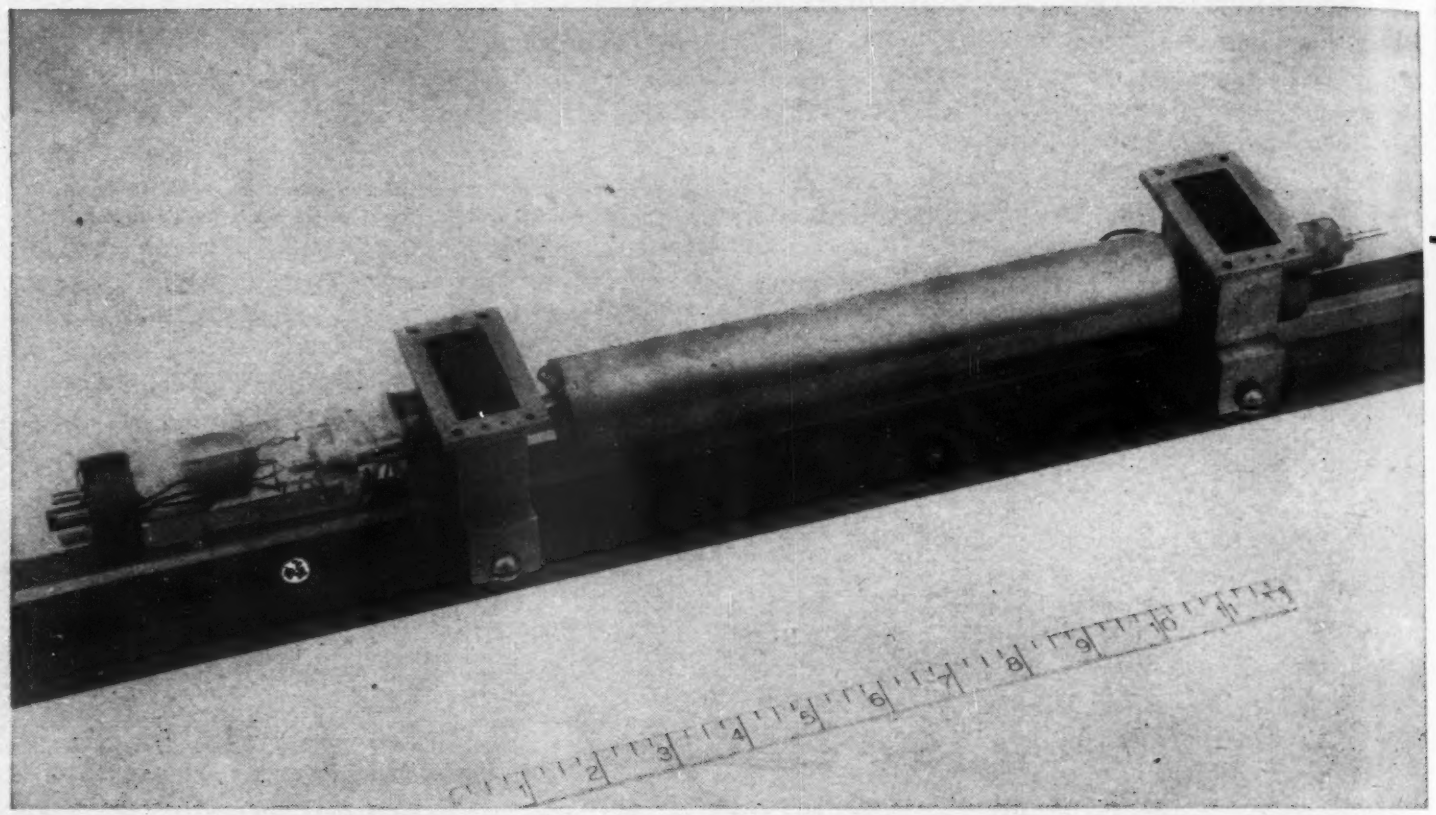


FIG. 1—The traveling-wave tube projects through the input and output couplings of a waveguide circuit. Electron gun is at the left

THE TRAVELING-WAVE TUBE, ultimately to be used as a repeater on coaxial and radio relay circuits, is a wideband amplifier for frequencies in the vicinity of 4,000 mc. It has an operating bandwidth of 800 mc, which is limited primarily by the coupling between tube and microwave waveguide circuit.

The tube consists of an electron gun that projects a beam of electrons at a velocity one-thirteenth that of light down the axis of a metallic wire helix. Both ends of the helix terminate in antennas that couple to the external waveguide circuit. The wave from the waveguide is picked up at the end of the helix at which the electron beam enters, travels down the helix absorbing energy from the electron beam as it does so, and is reradiated at increased strength from the antenna at the other end of the helix.

The tube is now undergoing extensive tests at the Bell Telephone Laboratories to determine its operating characteristics and the circuits in which it is most useful.

Coupling Circuit

Whereas other forms of microwave tubes such as the klystron and magnetron depend on resonant cavities for coupling between the electron stream and the electromagnetic circuit, the traveling-wave tube obtains the coupling by means of nonresonant line. Resonant circuits are used to obtain a high field strength and hence efficient coupling. However, in tubes using resonant circuits, the coupling is confined to a relatively small region. By extending the region over which the electrons deliver their energy to the field, which is done in the traveling-wave tube by using a nonresonant transmission line instead of a short gap in a cavity, efficient coupling is obtained despite the necessarily weaker field of the nonresonant circuit. In this manner it is possible to obtain a very wideband amplifier for the microwaves.

Wave energy is coupled into the helix by an antenna. As shown in Fig. 1, the tube is mounted so that it projects through the terminating cavities of a waveguide transmission circuit, which in turn couples to the coaxial or radio link. There are antennas similar to electrostatic probes extending from the ends of the helix into the waveguides.

Characteristics and operating principles of the traveling-wave tube are explained in nonmathematical terms. The tube, designed for multichannel microwave relay systems, provides a high gain, wideband amplifier for use in television or f-m network circuits

The antenna at the input end of the tube couples to the receiving end of the incoming circuit; the antenna at the output end of the tube couples to the transmitting end of the outgoing circuit. The electromagnetic wave traveling down the waveguide circuit is picked up by the input antenna of the tube, travels down the helix, and is reradiated into the circuit by the antenna at the other end of the helix. These antennas must have sufficiently high Q to efficiently transfer the wave energy, but must be sufficiently broad in their tuning to transmit the wide band for which the tube is to be used. These two requirements are mutually exclusive, so a compromise design must be made.

The electron beam that leaves at the output end of the tube is returned to the conductive circuit by a collecting anode as shown in Fig. 2. The velocity of the electrons is adjusted to be slightly greater than that of the axial velocity of the traveling wave. Although the electromagnetic wave travels along the wire of the helix at a velocity very near that of light, its axial velocity is less, depending on the pitch and radius of the helix ($V_A = v/2\pi rn$; where V_A is axial velocity, v is wave velocity along the wire, r is the helix radius, and n is the turns per inch of the helix).

Amplification

Gain is a function of the relative velocity between electron beam and traveling wave. Beam velocity is readily controlled by the accelerating potential in the electron gun. Tube gain rises as the initial beam velocity increases, passing through a maximum at a velocity slightly greater than that of the traveling wave, and falling off at higher velocities. The gain also increases with the number of electrons in the beam, which can readily be controlled by regulating the current

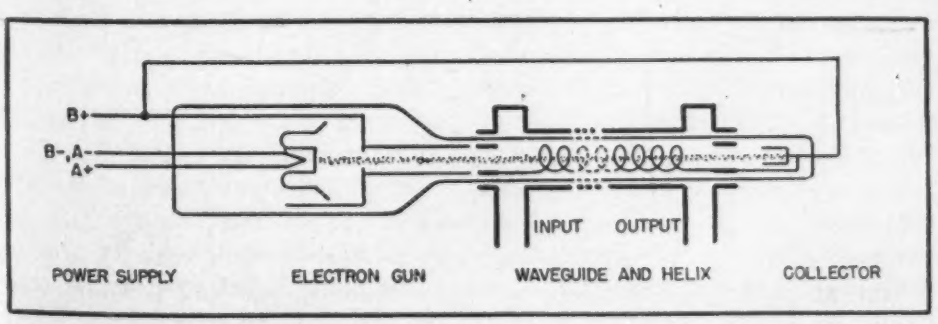
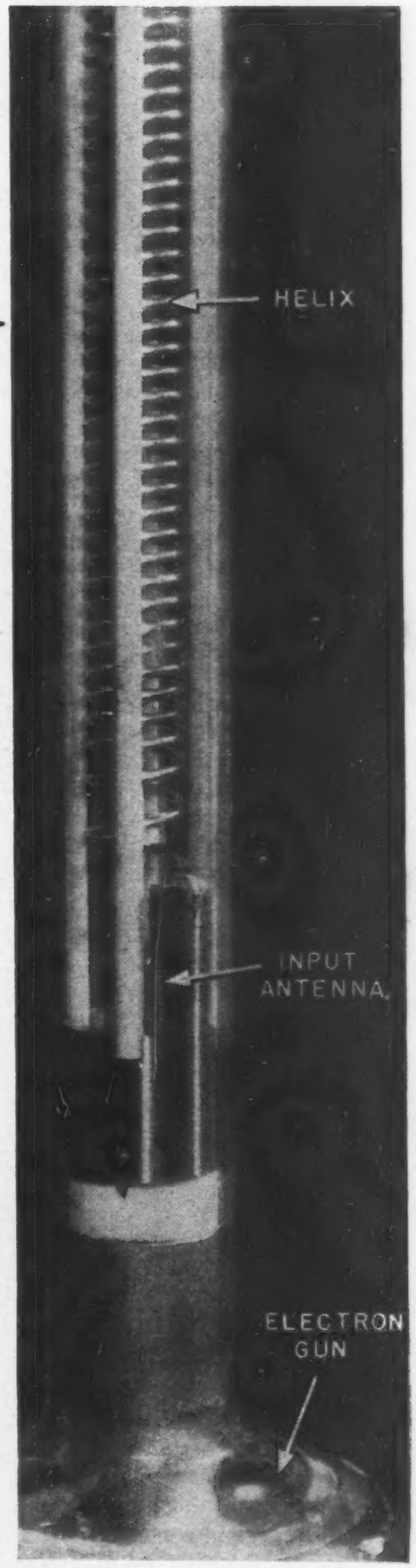


FIG. 2—Pictorial circuit shows how helix is coupled to waveguide at input and output ends. Guide extension along helix serves only as electrostatic shield



Tube provides nonresonant coupling between electron beam and traveling wave

from the cathode of the electron gun. Near the optimum velocity there is a self-regulating action of the electron beam on the wave velocity to maintain the proper relation between wave and electron velocities.

Because gain depends on velocity and density of the electron beam, operating potentials of the electron gun must be stabilized, or, if desired, variable losses over the microwave circuit can be compensated by an automatic volume control circuit operating on the electron gun potentials.

Gain also depends on the number of wavelengths along the axis of the helix, and is about a decibel per wavelength. Thus as the frequency is decreased, thereby reducing the number of wavelengths along the helix, the gain falls off. Amplification in the tube, as will shortly be explained in more detail, depends on the interaction between the beam electrons and the electric field established by the wave on the helix. As the frequency is increased, this wave field concentrates closer to the wire of the helix so that at high frequencies the field strength along the axis of the helix is weak and the gain is low. Thus there are inherent upper and lower limits of frequency for which a given tube amplifies. These limits lie far beyond those set by the antenna coupling problem mentioned before. Except for mechanical limitations, there is no reason why the tube could not be scaled to function at any desired region in the spectrum.

There are about forty wavelengths along the helix at the design center frequency. The transmission loss along the helix when the tube is cold is, in one experimental model, 30 db. When the tube is hot, it provides a gain of 20 db; however, a wave traveling the helix in opposition to the electron stream still suffers a 30 db attenuation.

That the tube transmission loss is more than its gain is desirable in that there will be no instability or tendency toward oscillation in case of impedance mismatch in the external circuit. If there should be a wave reflection caused by an impedance mismatch at the output of the tube, standing waves would appear along the helix lowering the efficiency. The high attenuation of the helix tends to reduce the standing-wave ratio should standing waves be present. However, proper terminations are essential for efficient operation.

Electron-Wave Interaction

Amplification depends on the interchange of energy between the

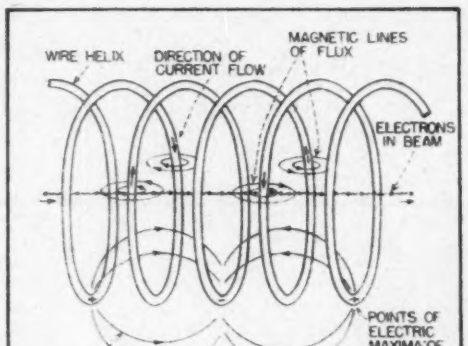

WIRE HELIX
DIRECTION OF CURRENT FLOW
MAGNETIC LINES OF FLUX
ELECTRONS IN BEAM
POINTS OF ELECTRIC MAXIMA OF POLARITY INDICATED
ELECTRIC LINES OF FLUX
WAVE MOVES ALONG HELIX

FIG. 3—Field diagram shows orientation of electric and magnetic lines of flux in relation to helix and electron beam. Coupling is only through electric field

electromagnetic field established along the axis of the helical coil and the electron beam traveling axially down the helix. Figure 3 shows representative lines of electric and magnetic flux of the traveling wave. These flux lines move with the electrons down the tube. Both electric and magnetic flux are parallel to the path of the electrons at the core of the helix. Thus there is interaction only between the electrons and the electric component of the field. (Magnetic flux acts only on the component of an electron's velocity that is perpendicular to that flux.)

The first function of the field is to bunch the electrons. Electrons entering the traveling-wave field at a region of positive potential gradient are accelerated; those entering at a region of negative potential gradient are decelerated. Because the entering velocity of the electrons is slightly faster than that of the traveling wave, the electrons are moving ahead, relatively, into the wave. (It is as if the wave were standing still and the electrons were moving slowly along it.) The result is that electrons entering the wave at a region of accelerating field pass quickly on into a region of decelerating field where they remain for a comparatively long time. Electrons entering the wave at a decelerating field region remain in that region for a long time. The result is that most electrons are in regions of decelerating field most of the time. Thus more electrons are being decelerated at any instant than are being accelerated. As a consequence there is an over-all absorption of energy from the electron beam by the wave field. Momentum of the electrons is transformed into field energy in the wave.

That the electrons enter the wave field at a critical velocity slightly greater than the axial velocity of the wave is essential to transfer of energy. Were the electrons to travel at the velocity of the traveling wave, they would reach their greatest bunching in a field of zero potential gradient, but because the beam enters the traveling wave at a slightly higher velocity, the electrons concentrate within the decelerating field where their kinetic energy can be transformed into electric energy. The variation of amplification with change in initial beam velocity is caused by the bunch forming more or less within the region of greatest negative potential gradient. Because of the dual action of the beam as bunching agent and energy absorbing medium, neither the condition for optimum bunching nor for optimum energy absorption can be realized. Rather, the condition that combines these functions in the proportions to give greatest amplification must be established.

During the war, R. Kompfner and others in the Clarendon Laboratory at Oxford showed that amplification was possible with a device consisting of an electron stream and a helix. J. R. Pierce and L. M. Field at the Bell Telephone Laboratories have successfully produced such an amplifier with the astonishingly high gain and broad band just described.

Practical significance of the tube can be appreciated by the fact that it provides more gain over a wider band than any other tube. It could handle 10,000 telephone conversations or several dozen television programs simultaneously.—F. R.

Duplex Operation of INDUCTION HEATERS

Multiple connection of identical units, for either two-phase or three-phase input, can be readily effected to provide twice the power of either unit operating alone

By W. C. RUDD

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IN THE PRODUCTION of high-frequency power for induction heating, it has been found advantageous to use multiple unit oscillators for the production of powers beyond the capabilities of a single unit.

The problem involves the interconnection of two independent high-frequency oscillators in a manner such that the output frequency of the two units is exactly the same and so that the tank circuits are locked in step. In addition, the total load must be shared equally by the two power supplies, and the load on the power line must be balanced.

Fundamental Unit

Each basic unit consists of a modified Hartley oscillator, as shown in Fig. 1. The equipment contained within the dotted line is in the cabinet of the oscillator. The radio-frequency output transformer may be at some distance from the oscillator.

The tank circuit within the cabinet consists of the tank capacitor and an inductor. The inductor, in conjunction with a grid coil, provides adjustable feedback. The balance of the tank inductance is in the primary of the radio-frequency output transformer. The work coil is connected to the secondary of this transformer and can be of single- or multiple-turn construction.

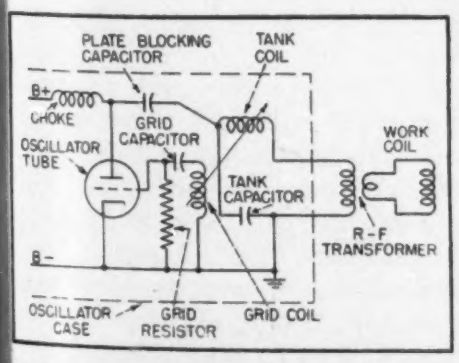
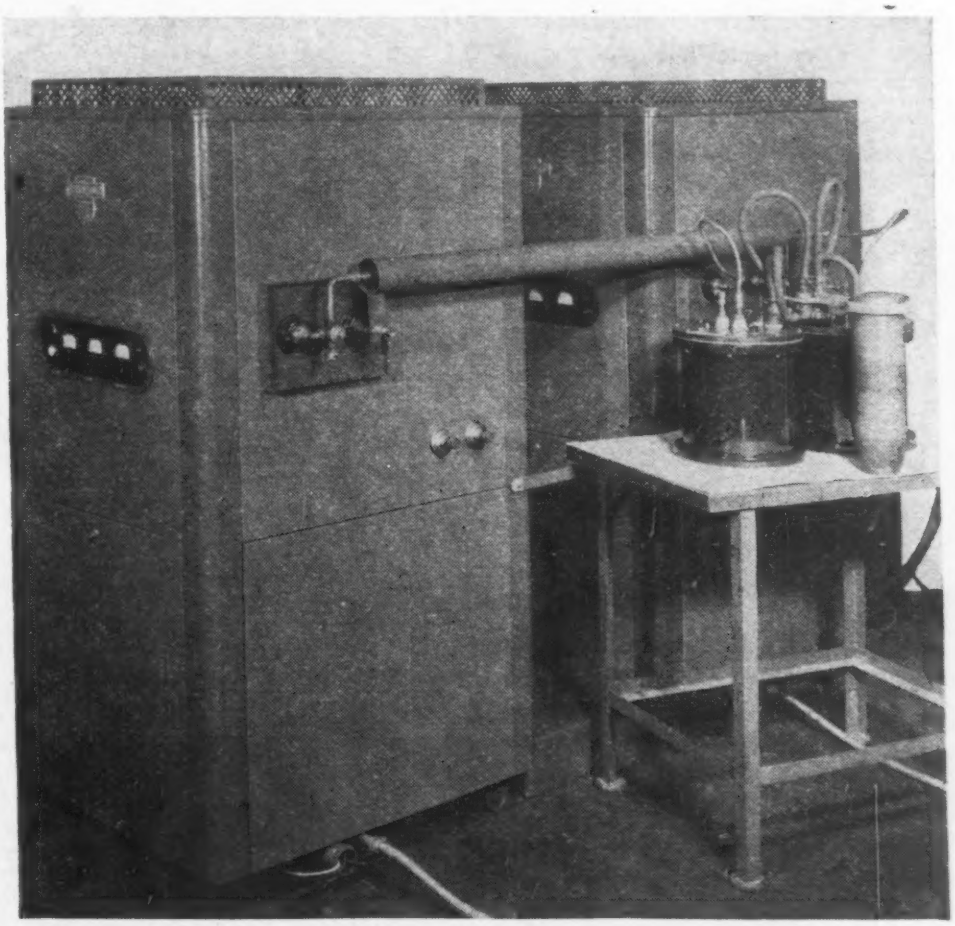


FIG. 1—Basic oscillator circuit, showing the variably coupled plate and grid coils. The r-f transformer is actually a part of the oscillator circuit but is located near the work



Side view of two heaters connected by a coaxial line to give double the power of a single unit in the common work coil. The two r-f transformers that feed the work coil rest on the table at the right

The basic oscillator has an output of twenty or more kilowatts, depending upon the power supply.

The power supply may be either single phase, full wave, unfiltered, or three phase, full wave, unfiltered. In the single-phase power supply, the plate transformer feeds four mercury-vapor rectifier tubes connected as a bridge rectifier. The output is pulsating direct current

at an average value of 9,000 volts. In this case, the power supply is capable of delivering 40 kilowatts of unfiltered power to the oscillator section.

The three-phase power supply consists of a single three-phase transformer feeding a six-tube mercury-vapor full wave rectifier. The output of the rectifier is 12,500 volts with a 5 percent ripple. The power supply is capable of delivering 50 kilowatts of unfiltered d-c power.

Synchronizing Tank Circuits

In order to connect two oscillators together and to feed their output into a common work coil it is necessary to solve several problems. First, it is essential that the two separate tank circuits of the oscillators operate in synchronism; second, it is necessary that the two oscillators deliver equal power output; third, the total power output must equal twice the rated output of each oscillator.

The first requirement is accomplished rather simply. The two tank circuits are connected in series, using two r-f transformers. This connection is shown in Fig. 2 and the photograph. The circulating tank current will be the same in all parts of the circuit. The two tank capacitors are in series; therefore, the resulting total tank capacitance is one-half that of a single unit. The tank coils and r-f transformer primaries are connected in series. Therefore, the total tank inductance is twice that of a single unit. Hence, with one half the capacitance and twice the inductance, from the usual resonant circuit frequency formula $f = 1/(2\pi\sqrt{LC})$ it is seen that the frequency remains the same and, since we now have a tank circuit common to the two oscillators with the same tank current, the two must of necessity be in synchronism. The only difference between this setup and the conventional circuit is that the tank circuit is fed at two points instead of the usual single point. Each oscillator receives grid drive from its own grid coupling coil and, since both coupling coils are electromagnetically coupled to a common tank circuit, the grids are driven in the proper relationship to each other.

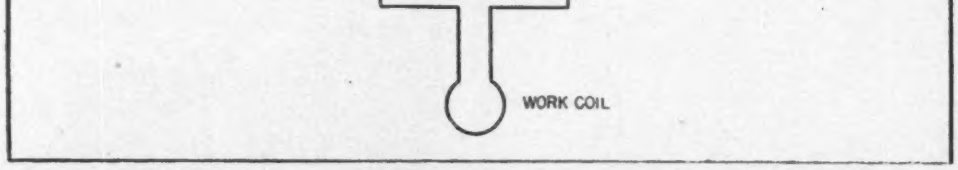


FIG. 2—Two oscillator r-f transformers and work coils can be wired in series for double power. A coaxial connection is necessary, besides other ground bonds, to maintain a low reactance between units and ground

By connecting the tank circuits in series a new tank circuit results, with two radio-frequency output transformers the secondaries of which are connected in series and grounded at the junction. The work coil is fed by the two transformer secondaries.

Low Reactance Tie

The connection of the two tank circuits in series involves only one problem. It will be noted that two separate ground connections are required since the oscillators must remain as originally wired to operate separately. The common ground bond between the two units in series will carry full tank current, amounting in some cases to several hundred amperes. If the bond has appreciable reactance, dangerously high potentials may exist between ground and the frames of the oscillators. There may also be radio-frequency voltage between the cores of the relays and their coils that will break down insulation. Additional ground ties are made between the frames and the oscillators as shown in the photograph.

It was found necessary to reduce reactance of the interconnection by means of the coaxial line illustrated. Without the coaxial tie between the two oscillators, the voltage difference might be of the order of magnitude of one or two hundred volts, whereas with the coaxial connection and frame ground ties the difference between the two is reduced to a value of approximately fifteen volts, which is of no consequence.

Use of Multiphase Power Lines

If three-phase power supplies are used having an output ripple of only five percent no difficulty is encountered in loading the oscillators to twice the rated output. The energy drawn from the power lines is balanced on the three-phase lines inherently. In many cases, however, only single-phase power supply units are available.

If both oscillator power supplies are connected to the same phase of a three-phase system, operation will be satisfactory in that the power output will be twice the rated output of one unit. The power supply wave shapes and resulting tank current envelope are shown at the left of Fig. 3. However, there may be a serious disadvantage insofar as the power lines are concerned. If a three-phase line is used, one of the phases has a very large load and the other two are unloaded, with a resultant bad unbalance. It may therefore be desirable to put one oscillator on one

phase and the other oscillator on another phase, leaving a phase of the three-phase system unloaded. Under these conditions the power line will be more nearly balanced, but it will not be possibe to obtain twice the rated output from the oscillators because the oscillator tubes are receiving grid voltage that is induced by the tank current, and are operating on a plate voltage that is independent of the tank circuit. Since the tank circulating-current envelope is the result of two power supplies feeding a common tank circuit, it will not coincide with the wave shape of the voltage from each of the individual power supplies.

When one oscillator is on each of two phases of a three-phase line, the wave shape of the d-c output from each of the power supplies will be 120 degrees out of phase, as shown at the center of Fig. 3. The resulting tank current envelope is not symmetrical with respect to the plate voltage wave shapes, causing grid voltages that do not coincide with the individual plate voltage wave shapes to be fed to the individual oscillators. Also, due to the fact that the two power-supply waves are not symmetrical with respect to each other, it is only possible to obtain a little over 1.5 times the rated output of both oscillators. In addition, the three-phase power line supplying the two oscillators is out of balance.

These two problems in operation on three-phase power lines can be corrected in two steps. First, the two high-voltage outputs of the power supplies are connected together. This connection is called a B-plus tie, and is made with a short piece of high-voltage, single-conductor armored cable. When the two power supplies are connected together both oscillators receive identical plate supply voltage wave shapes, thus causing the grid-voltage envelope to simulate the shape of the power-supply wave. As the second step, a Scott transformer bank is installed between the three-phase power line and the two single-phase power supplies. Thus, the three-phase line is converted to two-phase. As a result, instead of being 120 degrees out of phase with respect to each other, the power-supply wave shapes are now 90 degrees out of phase with respect to each other, a symmetrical condition. These steps result in equal sharing of load by the two power supplies and an improved tank-current envelope shown at the right in Fig. 3. The output of the two oscillators is now equal to twice

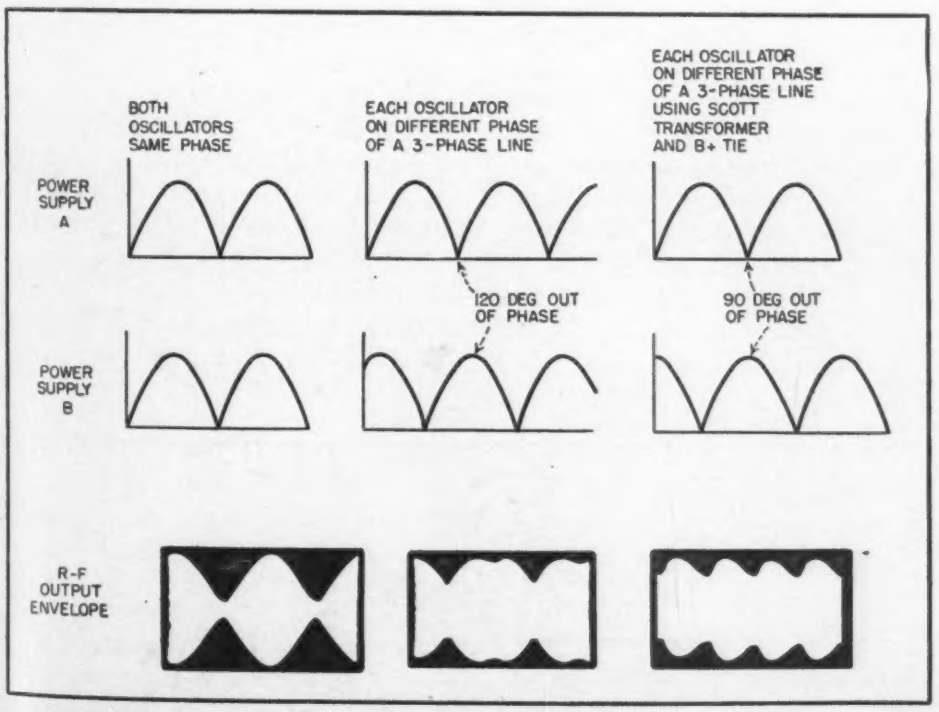

BOTH OSCILLATORS SAME PHASE
EACH OSCILLATOR ON DIFFERENT PHASE OF A 3-PHASE LINE
EACH OSCILLATOR ON DIFFERENT PHASE OF A 3-PHASE LINE USING SCOTT TRANSFORMER AND B+ TIE
POWER SUPPLY A
120 DEG OUT OF PHASE
90 DEG OUT OF PHASE
POWER SUPPLY B
R-F OUTPUT ENVELOPE

FIG. 3—Waveforms encountered in the output envelope when the heating units are connected in various ways to power lines. Double power can not be obtained from the two units unless the power input phasing is correct

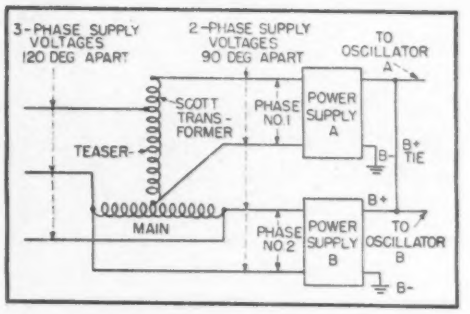


FIG. 4—Single-phase type units can be connected to a three-phase line through a Scott transformer. When the outputs of the power supplies are paralleled, the heating units give optimum power and the power line is also balanced

the rated output of one. The power supplied to the duplex unit is also balanced on the three-phase line.

The connections for this setup are shown in Fig. 4. On the left is shown the transformer bank, consisting of main and teaser transformers with a three-phase power input connection and a two-phase power-output connection, one phase of which goes to power supply *A* and the other phase to power supply *B*. The high-voltage outputs of power-supply *A* and *B* are connected together, as shown, with the B-plus tie. From here they feed the two oscillators with a duplicate wave shape.

Balancing the Oscillator Loads

The sharing of load between the two oscillators can be controlled in two ways. First, an adjustment of filament voltage to the bright tungsten filament tubes used will cause one oscillator to deliver more or less power, so that the load between oscillators can be balanced. As an alternative, small adjustable resistors installed in series with the grid-bias resistors can be used to increase grid bias slightly on the tube assuming the greater load. Once made, neither of the above adjustments need be changed until there is a replacement of oscillator tubes. Generally speaking, it has been found unnecessary to make any adjustment in the individual oscillators in order to realize reasonably equal load sharing.

In actual practice, installations have been made in which the change from single units to duplex is made by switching, and in which the time for change is less than a minute.

DESIGN OF F-M SIGNAL GENERATOR

Requirements of a reactance modulator for producing constant deviation of a variable oscillator are developed. Design data is given for an f-m signal generator covering 54 to 216 megacycles. Operation from 100 kilocycles to 25 megacycles is provided

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In the design of a frequency-modulation signal generator, the choice of the general type of circuit is considerably affected by the problem of modulation calibration. The usual reactance-modulator circuits produce deviations of the oscillator frequency which vary with the oscillator frequency. Since it is necessary to permanently calibrate the deviation obtained from the instrument, some means must be employed to maintain a constant modulator sensitivity over the frequency range. Two systems are available for accomplishing this purpose: the heterodyne system and the constant-deviation variable-oscillator system.

Heterodyne System

The basic operating principle of the heterodyne system is indicated in the block diagram of Fig. 1, which is reproduced from a paper[1] by A. W. Barber, C. J. Franks, and O. W. Richardson. In this system, frequency modulation of the fixed oscillator is controlled by variation of the modulating voltage applied to the reactance tube by means of a deviation control potentiometer. When the desired deviation has been chosen, this is necessarily held constant regardless of the output frequency, since it is the fixed oscillator that is modulated, and its frequency deviations are transferred unaltered to both the sum and difference frequencies which are generated in the mixer stage. The desired sum or difference frequency is amplified to obtain the required output voltage.

It is possible to gang the deviation control potentiometer to the variable tuning element of the variable oscillator to produce a constant deviation of the variable oscillator and to heterodyne this with an unmodulated fixed oscillator; however, modulation of the fixed oscillator is obviously preferable.

Although the many desirable features of the heterodyne system made it convenient for the original f-m broadcast band (42-50 mc), it is not well suited for a generator covering a large part of the vhf region. In addition to the desired sum or difference frequencies, the mixer output contains the harmonics of the two oscillators and the sum and difference frequencies of the various harmonics. These spurious frequencies are not harmonically related to the desired output frequency and, in fact, sometimes coincide with it[2]. To keep the output signal reasonably free from spurious signals over a wide frequency range, it is necessary to use the difference frequency and operate the oscillators at frequencies so high that frequency stability would be a major problem.

If sufficient oscillator stability could be attained, there would remain the problem of amplifying the desired signal in the mixer output. In the vhf region, this would require a tuned r-f amplifier. The problem of ganging the variable oscillator with an amplifier operating at the difference frequency is

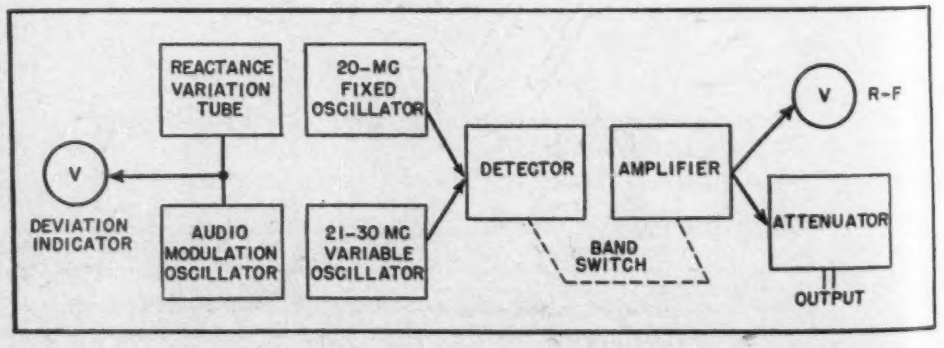
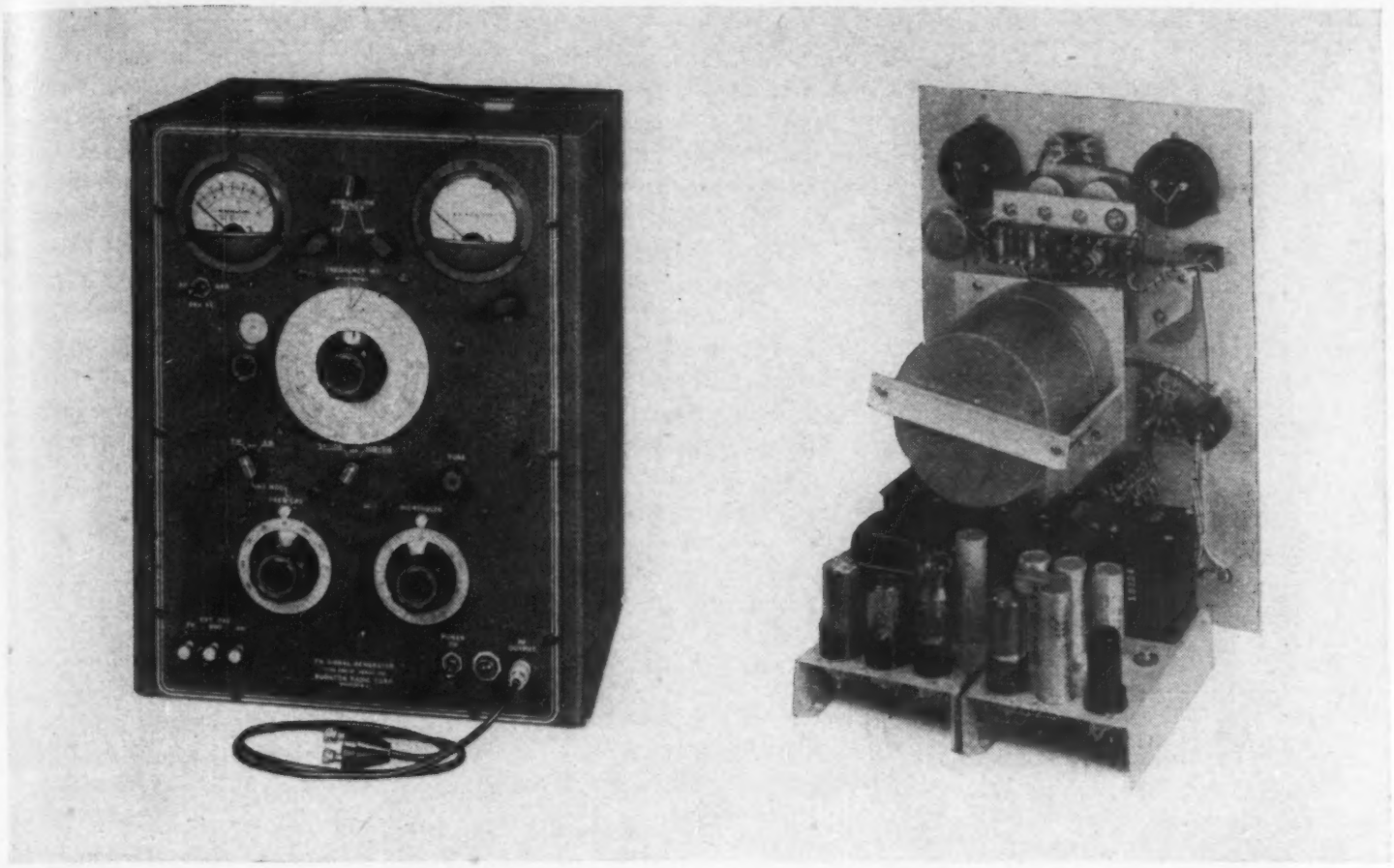


FIG. 1. Essential stages of f-m signal generator employing the heterodyne system



Front and rear views of the signal generator. Frequency deviation and percent of amplitude modulation are controlled by two potentiometers below the modulation meter switch. On the tuning dial, the vernier scale changes the frequency by about 26 kc on the low-frequency range and 52 kc on the high range. Choice of modulating frequency is provided by the dial at lower left and output from 0.0000001 to 0.2 volt is controlled by the attenuator dial at lower right

not very inviting since the rate of change of the output frequency is considerably different from the rate of change of the variable-oscillator frequency.

Constant-Deviation Variable-Oscillator System

If a constant-deviation modulation system is utilized, the signal generator does not require the step of heterodyning with its attendant spurious responses. Either an oscillator operating directly at the output frequency or a master-oscillator-multiplier arrangement may be used. Such arrangements confine the spurious responses to harmonics or subharmonics which are inherently low in output and are simply related to the output frequency so that they may be readily identified.

The constant-deviation system gives a greater output per tube used in the signal generator. With the elimination of the heterodyne step, only a single oscillator is required. Also, the efficiency of amplifiers or multipliers is considerably greater than that of a frequency converter.

In reactance-tube frequency modulation, there are two general types of reactance tubes employed. One type appears as a controllable inductance and the other as a controllable capacitance. The equivalent inductance or capacitance produced by the usual reactance tube with a two-element phase shifter results in an equivalent inductance or capacitance which is independent of frequency[3]. The reactance tube is placed in parallel with the tuned circuit to be modulated so that the inductive type may be considered as adding a controllable inductance in parallel with that of the tuned circuit while the capacitive type adds a controllable capacitance in parallel with the tuned-circuit capacitance.

For the inductive type of reactance tube, the resulting total tuned-circuit inductance is that of the tuned circuit and the reactance tube in parallel or

$$L_t = L_e L/(L_e + L) = L/(1 + L/L_e) \qquad (1)$$

where L is the fixed inductance of the tuned circuit and L_e is the effective inductance of the reactance tube.

When Eq. 1 is inserted in the expression for the resonant frequency of the tuned circuit, the frequency is given by

$$f = 1/[2\pi\sqrt{LC/(1 + L/L_e)}] = f_r(1 + L/L_e)^{1/2} \qquad (2)$$

in which C is the fixed capacitance of the tuned circuit and $f_r = 1/(2\ \pi\ \sqrt{LC})$. The quantity L/L_e is normally small in comparison to unity, so that Eq. 2 simplifies to

$$f = f_r(1 + L/2L_e) = f_r + f_r L/2L_e \qquad (3)$$

The second term in Eq. 3 is the frequency deviation which results from the reactance-tube modulation. It is seen to be proportional to the resonant frequency f_r and the ratio L/L_e between the tuned-circuit inductance and the effective inductance of the reactance tube.

For the capacitive type of reactance tube, the resulting total tuned-circuit capacitance is that of the tuned circuit and the reactance

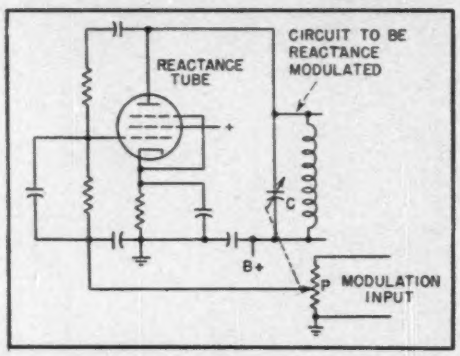


FIG. 2. Constant deviation is obtained by ganging a modulation input potentiometer with the tuning capacitor

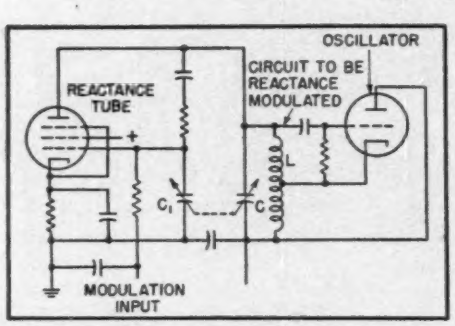


FIG. 3. Method of obtaining constant deviation by ganging an element of the phase shifter with the tuning capacitor

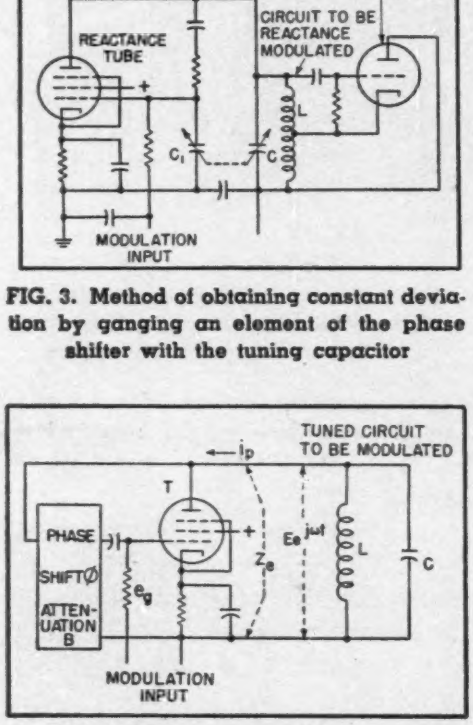


FIG. 4. Fundamental reactance-tube circuit

tube in parallel. The frequency is then given by

$$f = 1/[2\pi\sqrt{L(C + C_e)}] = f_r(1 + C_e/C)^{-1/2} \quad (4)$$

For the practical case, C_e/C is small compared to unity, so that

$$f = f_r(1 - C_e/2C) = f_r - f_rC_e/2C \quad (5)$$

It is thus seen that the frequency deviation produced by the capacitive type of reactance tube is proportional to the resonant frequency f_r and to the ratio C_e/C of equivalent reactance-tube capacitance to tuned-circuit capacitance.

The manner in which the frequency deviation varies with resonant frequency is also dependent upon which element of the tuned circuit is varied. If the tuned circuit is of the variable-capacitance, fixed-inductance type, and the reactance tube is of the inductive type, the frequency deviation may be taken from Eq. 3 which is $f_rL/2L_e$. In this type of circuit, L is fixed and L_e is independent of frequency. The result is a fixed percentage variation of inductance which produces a fixed percentage frequency variation. The frequency deviation in cycles is therefore proportional to the resonant frequency.

If the tuned circuit is of the variable-capacitance fixed-inductance type, and a capacitive reactance tube is used, the percentage capacitance variation varies with frequency as the tuning capacitor is varied. That is, the ratio C_e/C varies with frequency since C is varied. The value of C is varied in accordance with the formula $f_r = 1/(2\pi\sqrt{LC})$, which may be rewritten

$$C = 1/[L(2\pi f_r)^2] \quad (6)$$

Substituting Eq. 6 in Eq. 5 gives

$$f = f_r - 2\pi^2C_eLf_r^3 \quad (7)$$

In the frequency deviation given by the second term in Eq. 7, the quantities C_e and L are independent of frequency for the fixed-inductance type of tuned circuit. The percentage frequency deviation is thus proportional to the square of the resonant frequency. The deviation in cycles is proportional to the third power of the resonant frequency.

If the tuned circuit is of the variable-inductance fixed-capacitance type and the reactance tube is inductive, the ratio L/L_e varies with frequency. The tuned circuit inductance L is tuned in accordance with $f_r = 1/(2\pi\sqrt{LC})$, which may be rearranged to

$$L = 1/[C(2\pi f_r)^2] \quad (8)$$

Substituting Eq. 8 in Eq. 3 gives

$$f = f_r + 1/[(2\pi)^2L_eCf_r] \quad (9)$$

The values of L_e and C are independent of frequency for this combination so that the frequency deviation is inversely proportional to the resonant frequency. The percentage frequency deviation is therefore inversely proportional to the square of the frequency.

When the fixed element of the tuned circuit and the reactance tube type are the same (both capacitive or both inductive), the deviation sensitivity is proportional to the operational frequency. With fixed C in the tuned circuit and an inductive type reactance tube, deviation is inversely proportional to frequency. With fixed L in the tuned circuit and a capacitive type reactance tube, the deviation is directly proportional to the third power of the frequency.

The nearest approach to constant-deviation operation that may be obtained with the conventional reactance-tube circuits is a deviation which is either directly or inversely proportional to the operational frequency. Two combinations of reactance tube and tuning element produce deviations proportional to frequency. One of these is obtained by the familiar variable-capacitance tuned circuit in combination with an inductive reactance tube, and the other is obtained by a variable-inductance (such as a permeability-tuned) circuit in combination with a capacitive reactance tube. When either one of these combinations is employed, the deviation increases with frequency so that some means must be provided to reduce the deviation sensitivity as the frequency is increased.

Correction Methods

Various means may be applied for correcting the inherent deviation variation with frequency. One method is to gang a modulation input potentiometer with the tuning dial as shown in Fig. 2. Potentiometer P is designed to have a resistance taper such that, when ganged to the shaft of tuning capacitor C, the modulation sensitivity is maintained constant as the frequency is varied. For the circuit shown, the potentiometer reduces the modulation input as the frequency is increased.

Figure 3 shows how the modulation sensitivity may be maintained constant by ganging an element of the reactance-tube phase shifter to the shaft of the tuning dial. For the inductive-reactance tube and variable-capacitance tuned circuit shown, phase-shifter capacitor C_1 is ganged to tuning-capacitor C in such a manner that C_1 is increased as C is decreased. This increases the phase-shifter attenuation as the frequency is increased so that the degree of modulation produced by the reactance tube falls off with frequency sufficiently to produce con-

stant deviation. A particular shaping of the plates of C_1 with relation to those of capacitor C is required.

In the circuit of Fig. 3, the attenuation of the phase-shifter is mechanically varied to produce constant-deviation operation. It is also possible to arrange constant-deviation sensitivity over a given frequency range by means of a particular phase-shifting network which inherently produces the required phase shift and has the proper attenuation characteristic. The requirements of such a network may be seen from the following analysis.

Equivalent Circuits

In the reactance-tube circuit of Fig. 4, the plate circuit of tube T appears as a reactance by virtue of, the reactive current it draws due to the phase-shifted voltage fed from the plate to the grid. The impedance looking into the plate circuit is given by

$$Z_e = E\,e^{j\omega t}/i_p \qquad (10)$$

If the input impedance of the phase-shifter is assumed to be negligibly high, the current i_p is

$$i_p = e_g G_m \qquad (11)$$

in which G_m is the transconductance of tube T. The grid voltage e_g is

$$e_g = BE\,e^{j(\omega t + \phi)} \qquad (12)$$

in which B is the attenuation of the phase-shifter, expressed as a fraction less than unity, and ϕ is the phase shift produced by the phase-shifter. Substituting Eq. 12 in Eq. 11, then substituting the resulting plate current in Eq. 10 gives

$$Z_e = E\,e^{j\omega t}/G_m BE\,e^{j(\omega t + \phi)} = e^{-j\phi}/BG_m \qquad (13)$$

$$Z_e = (\cos\phi - j\sin\phi)/BG_m = R_e + jX_e \qquad (14)$$

in which

$$R_e = \cos\phi/BG_m \qquad (15)$$

and

$$X_e = -\sin\phi/BG_m \qquad (16)$$

Thus the impedance looking into the plate circuit of the reactance tube is composed of a series combination of a resistance R_e and a reactance X_e. If ϕ is between zero and +180 degrees (leading) the equivalent reactance is negative and therefore represents a capacitance. Likewise, if ϕ is between zero and −180 degrees (lagging), the equivalent reactance is positive and represents an inductance. For the practical case in which ϕ is close to ±90 degrees, the resistive component may be neglected and the reactance becomes

$$|X_e| = 1/BG_m \qquad (17)$$

In the case of the inductive type of reactance tube, the equivalent inductance is

$$L_e = X_e/\omega = 1/\omega BG_m \qquad (18)$$

When the equivalent inductance of Eq. 18 is inserted in 3, the frequency is

$$f = f_r + f_r\omega LBG_m/2 = f_r + \pi LBG_m f_r^2 \qquad (19)$$

Thus, with a fixed phase-shifter attenuation B and tuning inductance L, frequency deviation is proportional to the square of the resonant frequency f_r. Hence, by using an inductive reactance tube with a phase-shifter attenuation inversely proportional to the square of the frequency, constant-deviation operation may be obtained with a fixed-inductance, variable-capacitance tuned circuit.

In the case of the capacitive reactance tube, the equivalent capacitance is

$$C_e = 1/\omega X_e = BG_m/\omega \qquad (20)$$

Inserting C_e from Eq. 20 in Eq. 5 gives

$$f = f_r - f_r BG_m/2\omega C = f_r - BG_m/4\pi C \qquad (21)$$

The deviation term $-BG_m/4\pi C$ in Eq. 21 shows that the deviation is independent of frequency if the phase-shifter attenuation B and the tuned circuit capacitance C are also independent of frequency. Hence, constant-deviation operation may be obtained by the use of a fixed-capacitance, variable-inductance tuned circuit and a capacitive-type reactance tube employing a phase-shifter having an attenuation independent of frequency.

Figures 5 and 6 show capacitance-tuned circuits and inductive-reactance tube arrangements which produce constant frequency deviation over a range of frequencies. The resulting phase-shifter attenuations have the general shape shown in Fig. 7. The attenuation is such that the phase-shifter output amplitude is inversely proportional to the square of the frequency over the tuning range ($B \propto 1/f_r^2$, assuming constant phase-shifter input). The normal attenuation produced by conventional two-element phase-shifters is an output amplitude inversely proportional to the first power of the frequency, $B \propto 1/f_r$. In Fig. 5, this inverse square-law characteristic is obtained by tuning L_1C_1 to frequency F_t in Fig. 7. Tuned circuit L_1C_1 operates on the capacitive side of resonance and therefore appears as a capacitance to produce an inductive-reactance tube.

In Fig. 6, the bridged-T network R_1R_2 and $C_1C_2C_3$ is tuned to locate its rejection frequency at the frequency F_t. This network is capable of constant-deviation operation over a frequency range of about two-to-

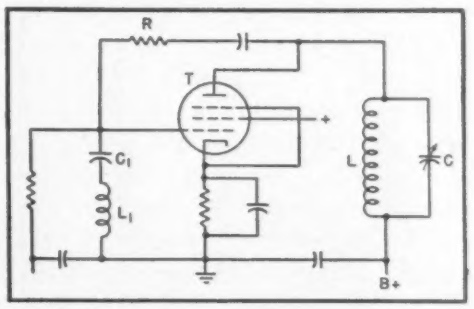


FIG. 5. Constant-deviation reactance-tube circuit. Phase shifter R, C_1, and L_1 produces an attenuation inversely proportional to the square of the frequency over the tuning range

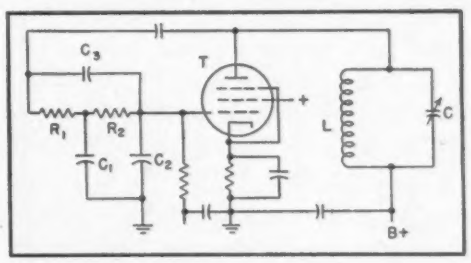


FIG. 6. In this constant-deviation network, the required inverse-square attenuation is obtained by the bridged-T phase-shifting network R_1, R_2, C_1, C_2, and C_3

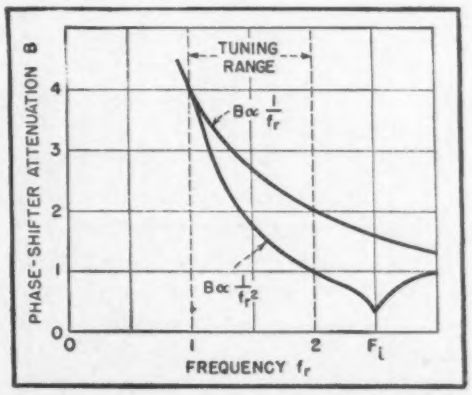


FIG. 7. Attenuation $B \propto 1/f_r$ produced by conventional two-element inductive reactance-tube phase shifter and attenuation $B \propto 1/f_r^2$ required by an inductive reactance tube for constant deviation of a capacitance-tuned circuit

one, while the network of Fig. 5 covers a range of about 1.5 to one. The exact magnitude depends upon the constancy of deviation required.

Over-All Design

A frequency coverage of two-to-one can be obtained by coupling an attenuator to the modulated oscillator. This system is not suitable for a wider frequency coverage since the phase-shifting network and the oscillator tank coil have to be switched. The network is rather critical and switching of this circuit at very high frequencies would probably lead to trouble.

A design which permits a four-to-one frequency coverage without switching oscillator and modulator circuits is obtained by following the oscillator with a class-C stage whose tank coil is switched to operate either as an amplifier or as a doubler. This design permits the oscillator and modulator to operate at half the frequency of the high output-frequency range. At lower frequencies, the effects of stray and residual reactances are not as troublesome as they would be at the higher frequencies. It also permits amplitude modulation of the output stage.

This design is not entirely satisfactory because some undesired amplitude modulation is produced during frequency modulation of the oscillator and the oscillator voltage is not sufficient to permit the class-C stage to remove this spurious amplitude modulation by limiting. A second objection is that amplitude modulation of the class C stage produces a considerable amount of spurious frequency modulation of the oscillator. Both of these objections can be removed by adding a second class-C stage.

The design which proved to be most satisfactory is shown in Fig. 8. The reactance-modulated oscillator operates from 27 to 54 megacycles. This is followed by a doubler stage and an output stage. The output stage operates either as an amplifier or as a second doubler (quadrupler), thus providing frequency coverage from 54 to 216 megacycles. This design provides the maximum of stability and simplicity since the oscillator and modulator operate at a relatively low frequency and the only r-f switching required is to switch a ground contact on the output coil.

The reactance tube uses a bridged-T type network similar to that of Fig. 6, in which C_2 and C_3 are replaced by the input capacitance and the grid-to-plate capacitance of the reactance tube. Capacitor C_1 is made variable and ganged with the tuning capacitor to provide the precision of deviation calibration required in a signal generator.

The slotted stator of C_1 is visible in the foreground of Fig. 9. By bending the sections of the stator, the deviation can be made as constant as desired over the entire frequency range. Resistor R_4 is bypassed for r-f only so that it causes degeneration at modulation frequencies and is used as a modulation sensitivity control. Resistor R_3 controls the cathode bias by bleeding current through the cathode resistor and is used to adjust the modulator tube to its most linear operating point. Total rms distortion of less than one percent at 75-kc deviation can be obtained with a modulating signal containing less than one-half percent distortion.

Doubler Tracks

A conventional self-biased class-C doubler is used. This stage tracks with the oscillator if the inductance of the tank coil is made one-fourth that of the oscillator tank and an identical capacitor section is employed. However, a higher tank circuit impedance can be obtained by decreasing the capacitance and correspondingly increasing the inductance. The requirements for tracking are that the shape of the capacitor plates be identical and that the ratio of maximum capacitor-and-circuit capacitance to total minimum-capacitance in the doubler circuit be the same as for the oscillator circuit.

Amplitude modulation is produced by modulating the screen circuit of the output stage. Since the power required is small and comparable with that required for frequency modulation, a simple resistance-tuned modulating oscillator serves for either amplitude or frequency modulation. Distortion is less than 3.5 percent for amplitude-modulation depths up to 50 percent. Due to the effective buffer action of the doubler stage, the spurious frequency modulation produced during amplitude modulation is small.

Frequency range switching is accomplished by providing the output tank coil with two contact points, one or the other of which is grounded by spring-contact fingers actuated by the frequency range switch. This method avoids most of the mechanical and electrical difficulties of coil switching.

In the output tank circuit, a high Q was desired to reduce the harmonically-related spurious output signals, while a low Q was desired to reduce the amplitude modulation

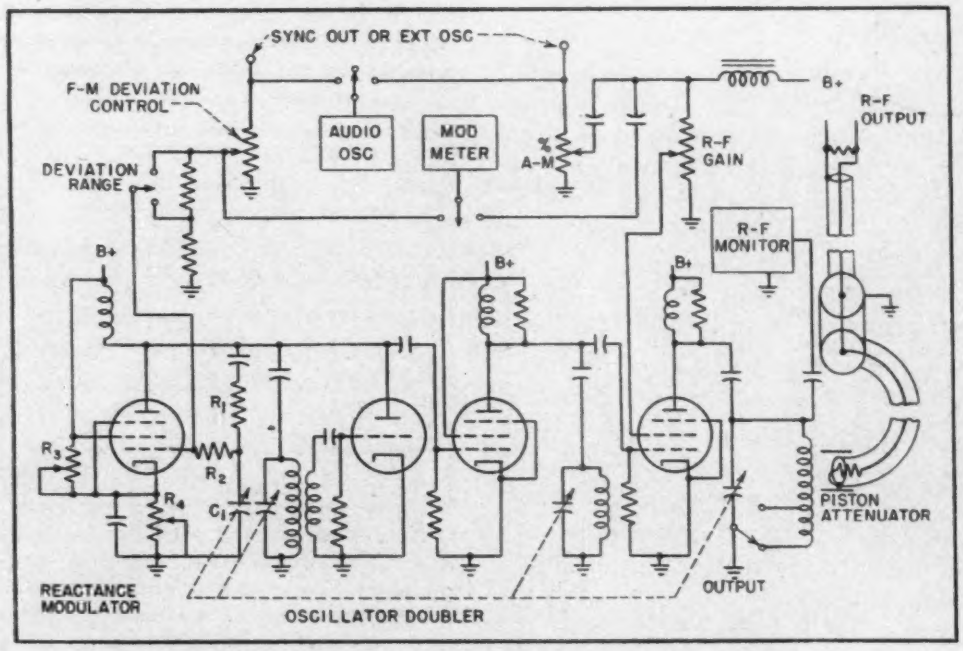


FIG. 8. Simplified diagram of the f-m signal generator

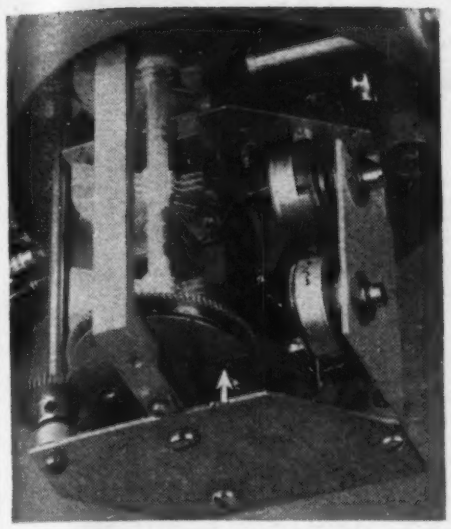


FIG. 9. Mechanical details of the r-f assembly. The arrow indicates the slotted stator of C_1

introduced on frequency-modulated signals by the selectivity of the circuit. In the final design, the damping was adjusted to reduce spurious signals to more than 35 decibels below the desired signal. The resulting amplitude modulation at 75-kc deviation is about two percent.

A mutual-inductance (piston) attenuator's is coupled to the tank-circuit inductor of the output stage. This is a simple and accurate attenuator for the vhf range since the rate of attenuation is dependent only on the inner diameter of the attenuator tube after sufficient attenuation has been introduced to suppress undesired modes of propogation of the electromagnetic field in the tube. The attenuator dial is calibrated from 0.1 microvolt to 0.2 volt; correction being made for a slight nonlinearity at the high-voltage end of the range.

Figure 10 shows the design of the output system. The voltage induced in the attenuator coupling loop L_2 in Fig. 10A is

$$e' = I\omega M = \frac{E}{\omega L_1}\,\omega k\sqrt{L_1 L_2} = EK\sqrt{L_2} \qquad (22)$$

where $\omega = 2\pi$ times the frequency and k is the coefficient of coupling between L_1 and L_2.

This equation shows that e' is a function of the tank voltage E and the coefficient of coupling k only. The attenuation law of the piston attenuator controls k. Voltage E is monitored by a voltmeter of the set-to-line type, the level being adjusted by a control in the screen circuit of the output tube. The output tank coil is physically flattened on the side facing the attenuator to present a more uniform field to the attenuator and permit larger values of k than are obtainable with a coil of circular cross-section. Although tank voltage E is smaller when doubling, the transformer ratio ($\sqrt{L_2/L_1}$ of Eq. 22) is larger and the allowable Q is greater. By placing the attenuator in proper relation to the tank coil, equal output is obtained on the two frequency ranges with very little change in the gain control setting.

A switch, ganged with the frequency range switch, actuates a precision voltage divider to halve the frequency-modulating voltage when the high-frequency range is being used since otherwise the deviation would be double that on the low-frequency range. A section of this unit switches calibrating resistors in the r-f monitoring voltmeter circuit.

Output

Standard 53-ohm RG58/U cable is used for the output cable. To keep the output impedance of the generator constant, a 53-ohm resistor is placed in series with the coupling loop and another is used to terminate the output cable. From Fig. 10B, the voltage e across the terminating resistor is then:

$$\left|e\right| = \left|\frac{53\,e'}{106 + j\,(\omega L_2)}\right| = \frac{53\,e'}{\sqrt{(106)^2 + (\omega L_2)^2}} \qquad (23)$$

Since L_2 is less than 0.01 microhenry, $(\omega L_2)^2$ can be neglected in comparison with $(106)^2$ and $e = e'/2$.

Neglecting L_2 in Fig. 10B, an application of Thevenin's theorem yields the equivalent circuit of the signal generator, shown in Fig. 10C. Thus the generator can be represented as a source e in series with a resistance of 26.5 ohms. The attenuator is calibrated in terms of the open-circuit output voltage e.

If the load impedance is not large compared with 26.5 ohms, the voltage applied to a load attached to the output terminals can be calculated by using the equivalent circuit of Fig. 10C.

To provide frequencies below the range of the signal generator, a converter consisting of a fixed oscillator operating at 70 mc, a linear mixer, and an amplifier which has flat response from 100 kc to 25 mc has been constructed. When the signal generator is tuned from 70.1 to 95 mc, the difference frequency of 100 kc to 25 mc is obtained from the converter. With frequency modulation the useful low-frequency limit is obviously dependent on the deviation employed.

By adjusting the over-all conversion-amplification of the converter for unity gain, the output voltage can be read directly from the attenuator dial of the signal generator without requiring an additional monitoring system or attenuator. Provision is also made for an uncalibrated voltage with about ten times the amplitude of

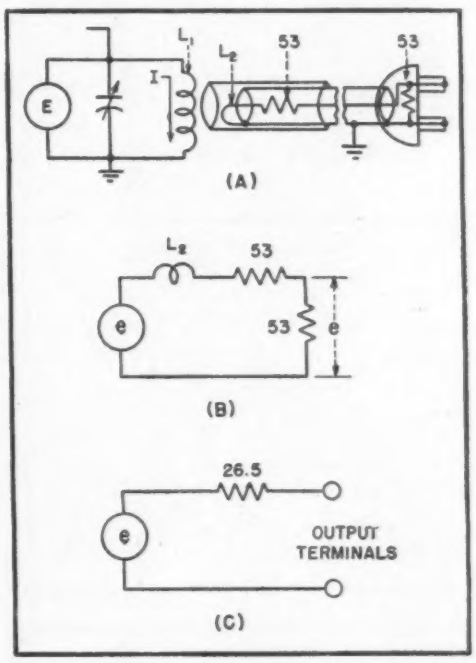


FIG. 10. Circuit (A) is the output system in which the D-shaped coil L_1 is used. The equivalent circuit of the attenuator is shown at (B) and the equivalent circuit of the signal generator at (C)

the input signal. The fixed oscillator is provided with a calibrated incremental trimmer capacitor for selectivity measurements.

The authors wish to acknowledge the considerable contribution of W. D. Loughlin to the success of the work reported in this paper.

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Flame Radiation

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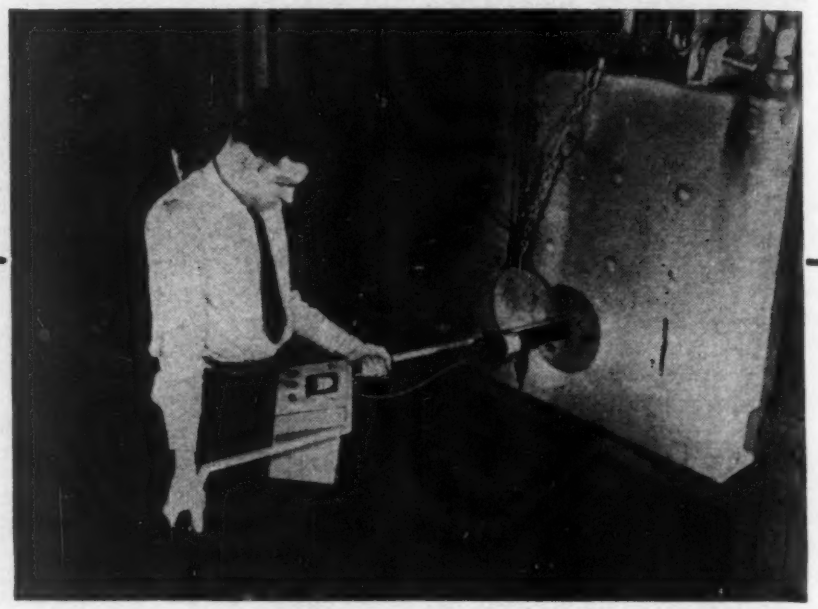


Flame radiation measuring instrument in use. This same furnace is shown in natural color on cover of this issue

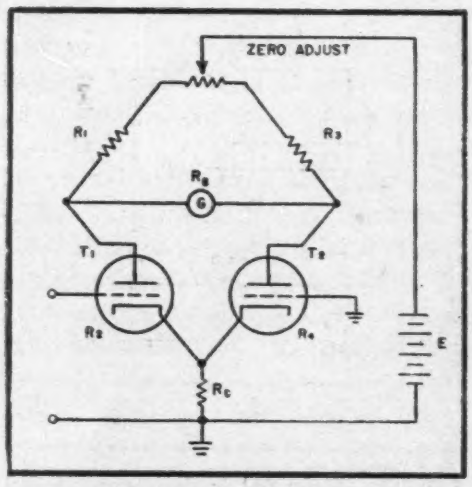


FIG. 1—Basic bridge-type vacuum-tube voltmeter circuit used with radiation pyrometer for flame radiation measurements

IN AN OPEN HEARTH steel furnace, transfer of heat from the flame to the charge depends largely upon radiation. This is especially true after the charge has melted, when it lies flat on the hearth and the flames sweep above it.

It is for this reason that measurements of flame radiation have for some time been made in steel mills. The basis of most practical measurements has been the radiation pyrometer, which develops an emf proportional to the total energy received. It consists of a group of tiny thermocouples upon which the radiant energy is focussed by a quartz lens or a mirror. The measuring equipment used ranges from sensitive voltmeters to electronic recording potentiometers. Good results can be obtained, but there are disadvantages in manipulation, portability, cost, or convenience.

Designing a voltmeter for this purpose is a problem when the small voltages to be measured and the factors of light weight and portability are given appropriate consideration in setting specifications.

It has been shown by investigators[1, 2] that furnace efficiency can be related to the total flame radiation, and that this is not necessarily dependent on flame temperature. One practical embodiment involved

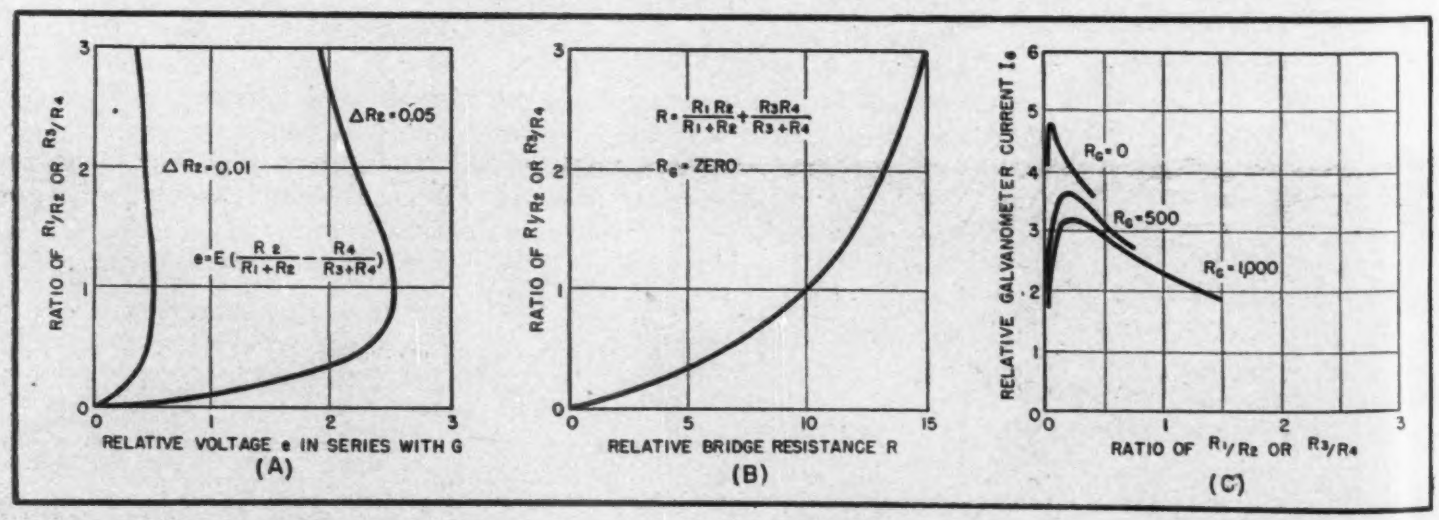


FIG. 2—Curves used in determining optimum values of circuit parameters for stable high-sensitivity vacuum-tube voltmeter

Measuring Instrument

Operating efficiency of open-hearth steel furnace can be checked quickly with highly stable bridge-type battery-operated vacuum-tube voltmeter connected to a radiation pyrometer that can be aimed at any desired portion of the 4,000-degree flame

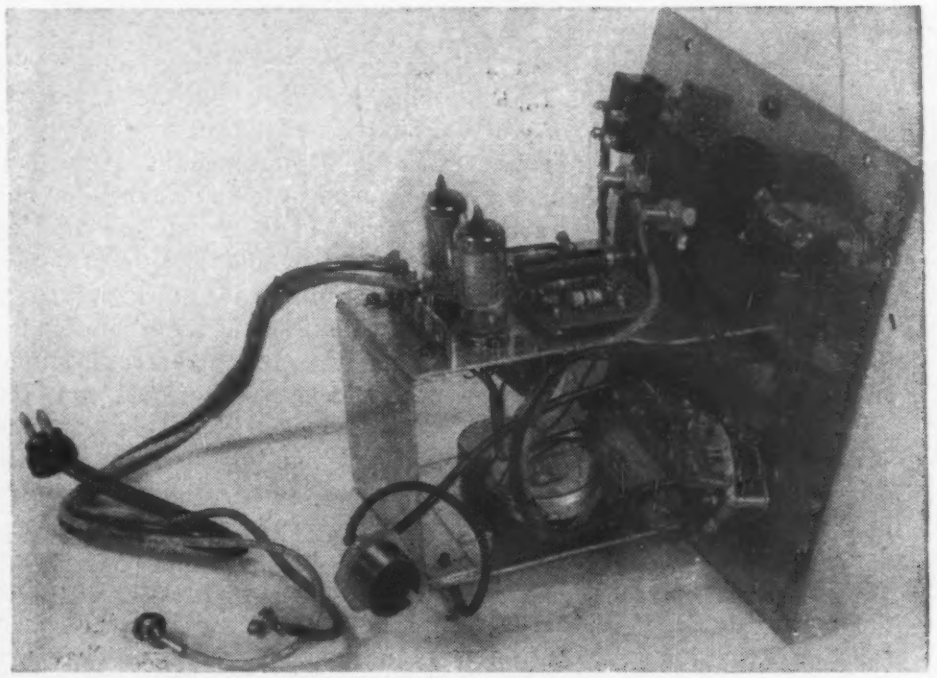
a recording potentiometer made portable by mounting it upon a wheelbarrow. By means of a hand-held scanning head containing a radiation pyrometer as a detector, flame radiation at each furnace door could be measured during the course of a heat. This equipment was effective but expensive, cumbersome, and inconvenient.

The portable battery-operated radiation-measuring instrument to be described was developed to overcome the drawbacks of earlier instruments in providing quick checks on firing conditions throughout a large shop.

Choice of Circuit

Because of the small permissible current drain in a radiation pyrometer it is not practical to use a microammeter directly as the indicating instrument. This suggested the use of a bridge-type vacuum-tube voltmeter.[3] The basic circuit chosen (Fig. 1) achieves the required stability by using vacuum tube T_2 as a fixed resistance in one leg of the bridge and by employing resistor R_G to provide degeneration.[4]

The design problem involved securing a sensitivity of the order of a galvanometer current of 50 microamperes for a grid input of 100 millivolts. This would give a deflection of at least half scale using a radiation pyrometer as a detector, when directed at flames of normal intensity in open hearth furnaces. To keep weight down, it was decided to limit supply voltages to 67½ volts and limit current drain to about 10 milliamperes.



Chassis of vacuum-tube voltmeter used to measure output voltage of radiation pyrometer. Battery and pyrometer connections are at left

A type 1S4 button-base tube having a 1.4-volt filament was found to be most suitable. When operated as a triode, it has a sufficiently low d-c plate resistance to compare favorably with the smaller power triodes for bridge use.

Design Procedure

To find an operating point that would be within the allowable battery drain, provide a low d-c tube resistance, be in a negative grid region, and utilize the available plate voltage to maximum advantage, design curves based on Thevenin's theorem were constructed. If the circuit of Fig. 1 is broken at point X, the voltage e at this point will be

$$e = E\left(\frac{R_2}{R_1 + R_2} - \frac{R_4}{R_3 + R_4}\right) \qquad (1)$$

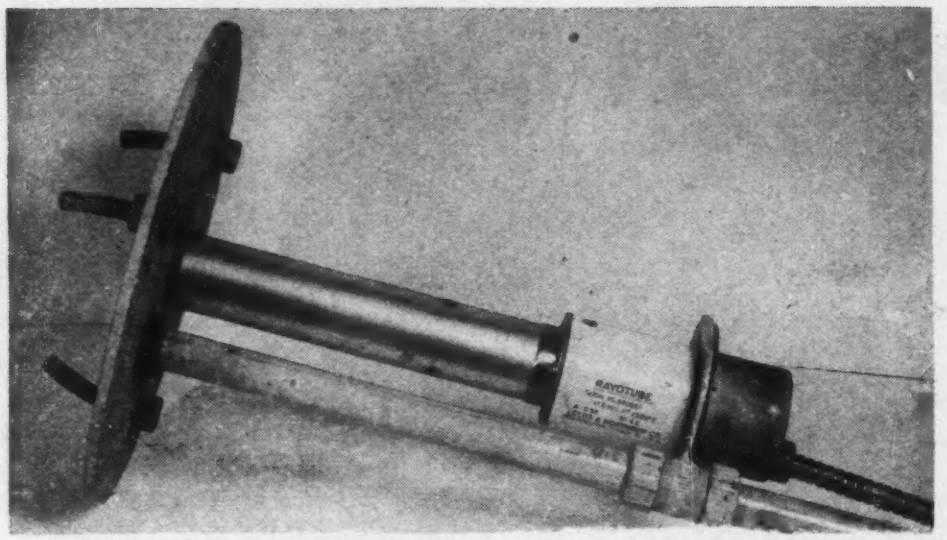
Plotting the bracketed term for two assumed increments of R_2 and various ratios of R_1/R_2 and R_3/R_4 gives the curves of Fig. 2A, which show that the greatest bridge voltage unbalance will be obtained when R_1 equals R_2 and R_3 equals R_4. The combined bridge resistance R in series with this potential then is

$$R = R_G + \frac{R_1 R_2}{R_1 + R_2} + \frac{R_3 R_4}{R_3 + R_4} \qquad (2)$$

Relative bridge resistance R for zero galvanometer resistance R_G is plotted in Fig. 2B for various ratios of R_1/R_2 and R_3/R_4. The current through the galvanometer will be

$$I_G = e/R \qquad (3)$$

For assumed increments of R_2 and



Radiation pyrometer (Leeds & Northrup Rayotube) used with bridge-type vacuum-tube voltmeter. Projecting lugs on heat shield at left engage wicket hole of furnace

R_4, relative values of I_G are plotted in Fig. 2C against ratios of R_1/R_2 and R_3/R_4 for several values of galvanometer resistance. These curves show that for usual galvanometer resistances the resistance ratios should be in the neighborhood of 0.2 to give maximum galvanometer current. This will allow the load resistors to be chosen.

Since a tube d-c plate resistance of a little over 10,000 ohms was expected at the operating point, a load of 2,250 ohms was assumed ($R_1 = R_2 = 2{,}250$) in order to make the resistance ratio equal to about 0.2. By trial, 1,000 ohms was found to be the largest value of R_G that could be used to approximate the desired operating point. Using these values in the circuit of Fig. 3 gave a sensitivity of 23.8 microamperes for an input signal of 50 millivolts, which is appreciably better than the minimum requirements.

The bias cell and voltage divider were provided so that at any time a known potential could be switched into the input to check calibration of the instrument.[5] A wire-wound zero-adjust potentiometer was used at first, but later replaced with a carbon control in order to get a stable adjustment for mobile use in the mill.

Operation of Instrument

To take a reading the instrument is placed at a furnace door so that lugs on the heat screen engage the wicket hole. This centers the radiation pyrometer in the aperture and assures an unobstructed view of the flame. Because of the rapid response of radiation pyrometers, a reading is obtained in a few seconds. The pyrometer can be aimed by means of the frame and sighted over quite an angle in the furnace.

The readings are left in arbitrary scale values since it is not intended to find furnace temperature, but to obtain comparative data on the radiating power of the flames. The readings can be converted, if desired, into millivolts pyrometer output. The results are affected by radiation from the furnace walls and the bath as well as by the flame, and this must be borne in mind when evaluating the readings. They are of comparative significance only in revealing efficiency of combustion.

It thus becomes possible with this type of instrument to obtain quickly a relative measure of furnace efficiency, free from errors of human judgment. By successively making changes in furnace control settings and taking readings of flame radiation, it is possible to find the best control settings and thus achieve higher average furnace efficiencies. One man can check five or six furnaces with the instrument in less than an hour.

The instrument is intended for use by combustion technicians to diagnose furnace troubles, and as a measuring tool to help them set up standard furnace adjustments.

This instrument was built in the electrical department of John A. Roebling's Sons Co. by regular personnel. The writer wishes to acknowledge the great assistance of Albert Buchanan, Special Electrician, in the construction of the unit. His clear understanding of the project contributed in large measure to the attainment of design expectations in a first model.

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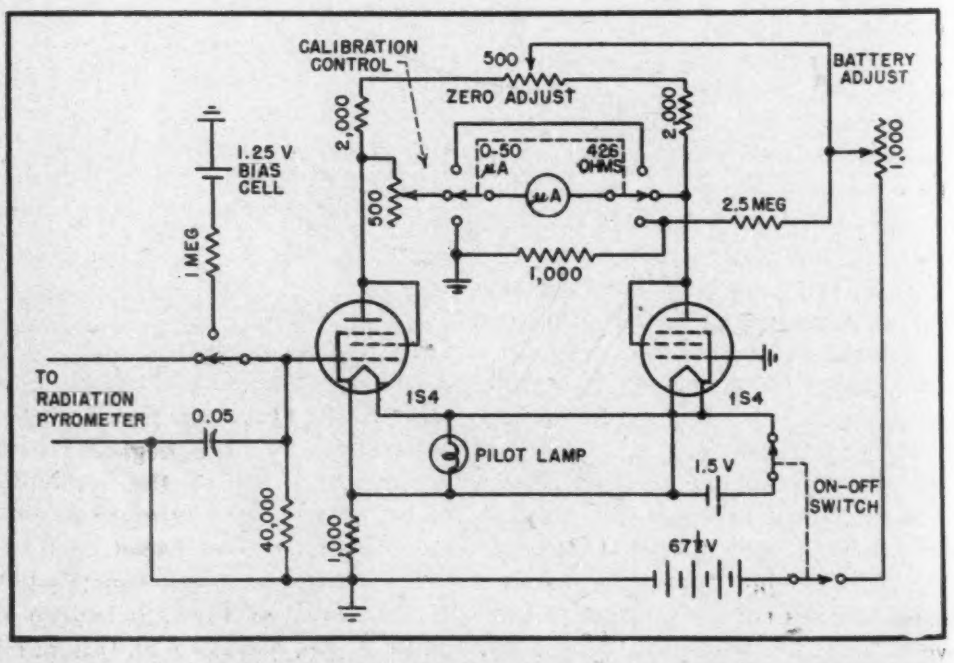

FIG. 3—Circuit of final instrument developed for flame radiation measurements

Logarithmic Photometer

USEFUL CIRCUITS

In describing a photometer of varied application the author presents several interesting electronic circuits including a method for obtaining logarithmic response to light intensity from a phototube, a system for correcting nonlinearity by automatically introducing meter shunts, and an improved connection of gaseous regulator tube between power supply and load. These circuits can be used in a variety of ways on other instruments

Multiplier phototube and circuit used to obtain logarithmic response to light intensity are described. Instrument gives linear meter indication of film density for use as direct-reading densitometer, or of concentration for metering chemical concentration by monochromatic optical methods

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IT is desirable, in a large number of photometric problems, to use a logarithmically responsive instrument.

In photography, brightness levels of ordinary scenes vary over an enormous range and it is therefore convenient to provide an exposure meter whose response is approximately logarithmic.

In measuring absorption characteristics of photographic films, results are customarily expressed in terms of optical density. Density is the logarithm of the reciprocal of transmissivity. By using a logarithmic phototube amplifier system, a uniform density scale can be obtained. One commercial densitometer which utilizes the logarithmic grid current versus plate current relationship existing in thermionic triodes is the Ansco Model 11 Densitometer[1]. A photomultiplier tube instrument based on this circuit has been described in the literature[2].

In chemical analysis, where chemical concentration of a solution is to be studied as a function of optical transmission of that solution (best done at a single wavelength), a logarithmically responsive photometer is desirable. Such a photometer gives a uniform scale of concentration values.

A number of papers have recently been presented which deal with the application of multiplier phototubes to spectrochemical analysis and to other photometric problems.[3, 4, 5] In general the effort has been to obtain a stable system of linear response and this aim has been achieved to a considerable extent, although logarithmic circuits have a number of advantages in such applications.

An ideal electronic photometer may be defined as one having the following characteristics: (1) high sensitivity, (2) good stability, (3) direct reading operation, as distinct from manual or automatically actuated null balance type, (4) logarithmic electrical response over an intensity range of at least 1,000 to 1, electrical, as distinct from mechanical, because devices which rely on magnetic or mechanical compensating features to obtain uniformity of response cannot readily be used in recording or computing circuits, (5) simplicity, (6) compactness, (7) low cost, and (8) flexibility of design.

Principle of Operation

The simplified circuit shown in Fig. 1[6] provides the basis for an instrument which meets these requirements unusually well.

Theoretically, sensitivity of electron multiplier tubes depends on applied dynode voltage according to the relation

$$S \leqq kV^{n/2} \qquad (1)$$

where S is sensitivity expressed in terms of anode current versus incident light (S is proportional to the electron current gain of the tube as a whole), V is dynode voltage per stage, n is number of stages, and k is a constant characteristic of the individual multiplier tube. From this relation it will be seen that if

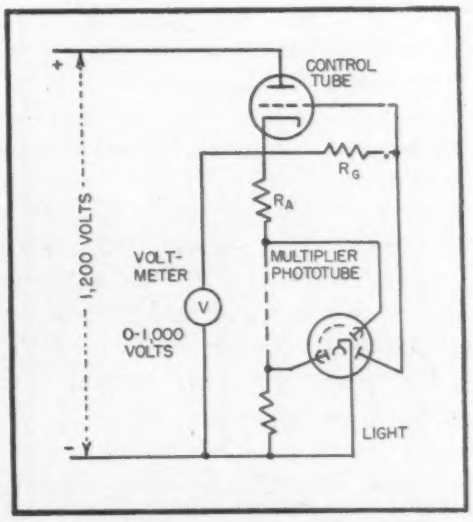


FIG. 1—Basic feedback circuit for producing logarithmic relation between light intensity and dynode voltage of multiplier phototube

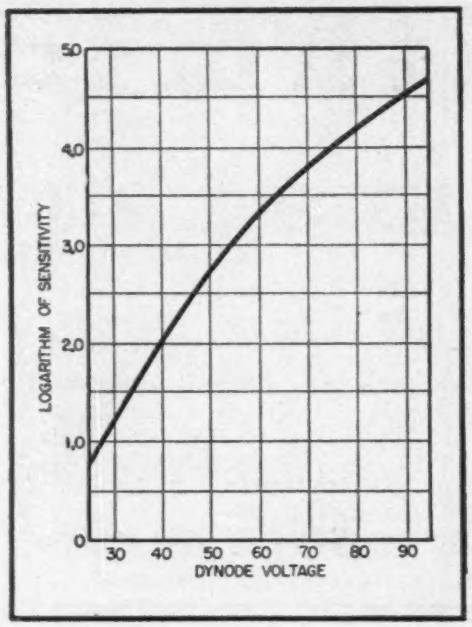
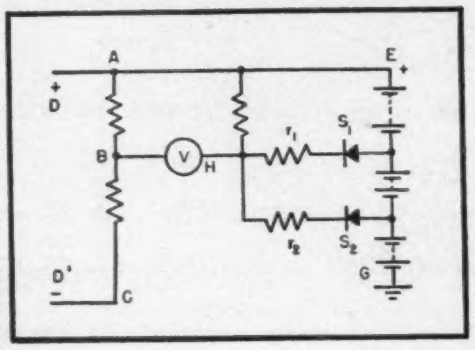


FIG. 2—(left) Were the transfer characteristic of the circuit of Fig. 1 ideally logarithmic, this response function would be a straight line

FIG. 3—(below) Automatic electrical introduction of meter shunts compensates for nonlinearity of phototube circuit response



the dynode voltage is adjusted so as to maintain constant anode current in the presence of variations in incident light intensity, the relationship between the logarithm of light intensity and voltage will be

$$\log F = -(n/2) \log V + k' \qquad (2)$$

where F represents radiant flux incident on the photocathode, $k' = -\log k$ and F is proportional to 1/S.

The circuit shown automatically and instantaneously performs this constant current operation. As the light intensity falling on the photosurface is increased, the anode current tends to increase too. However, as the anode current increases, the grid of the control tube is driven to a more negative potential. Consequently the bleeder current is reduced, the dynode voltage is reduced in proportion, and the sensitivity of the tube as a whole decreases. In the limiting case, wherein the control tube has a high amplification factor (virtually infinite) the control grid voltage (and therefore the anode current through the grid resistor R_g) is sensibly constant. Under ideal conditions anode impedance of multiplier tubes is relatively high so that ordinary variations in the anode-dynode No. 9 voltage have small effect on the light intensity versus bleeder current relationship.

Voltmeter Response

When a voltmeter is connected across the total bleeder circuit it will respond nearly uniformly to changes in the logarithm of light intensity. Theoretically the slope of the log F versus voltage curve is

$$\frac{d(\log F)}{dV} = -\frac{[(n/2) \log e]}{V} \qquad (3)$$

and $$\frac{d(\log S)}{dV} = \frac{[(n/2) \log e]}{V}$$

For practical multiplier tubes such as the 931-A or 1P21 the relationship for d (log S)/dV versus V indicated in Fig. 2 is representative and it will be observed that a range of 25 to 70 volts per stage corresponds to a sensitivity ratio of 1,000 to 1. It will be noted that the actual slope d (log F)/dV is reasonably uniform over this voltage range, more so than Eq. 3 indicates, and the slight nonlinearity of this function can be compensated by the corrective output circuit whose basic features are shown in Fig. 3.

If total dynode voltage is connected at DD′, selenium rectifiers S_1 and S_2 will be inoperative at voltage values of DD' which correspond to the condition wherein voltage AB is less than EF and EG. Under these circumstances resistors r_1 and r_2 are ineffective. At dynode voltages high enough to elevate AB above EF but lower than EG, S_1 will conduct current and resistor r_1 will act as a shunt resistance across the AB portion of resistor ABC. If the resistor network is designed properly, the rate of increase of voltage AB versus dynode voltage DD' can be modified to give the desired correction over a portion of the input range. By using two corrective shunts of this type it has been found possible to obtain a circuit which gives linearity accurate within ± 0.02 log F over a log F range of 0 to 3.

High-Voltage Supply

From a consideration of feedback principles involved in the operation of this circuit it is obvious that even large changes in supply voltage will not affect the dynode voltage (provided that the supply voltage does not fall below the minimum value required for the equilibrium bleeder voltage). In fact, changes in characteristics of the control tube, such as those due to aging and replacement have negligible effect on calibration of the instrument. If the circuit is properly designed only sensitivity versus dynode voltage characteristic of the multiplier phototube influences calibration of the instrument.

Figure 4 is a detailed schematic diagram of the complete circuit. The power supply consists of a conventional power transformer whose high voltage secondary winding energizes two type 816 hot cathode, high voltage, gaseous rectifiers in a full-wave voltage doubler circuit. Necessary voltage isolation of the heaters is obtained by using the 5-volt winding plus a voltage dropping resistor as a source for one of the filaments and the 2.5-volt winding directly for the other. The 100,000-ohm bleeder resistor and double section 3-μf filter capacitors used as indicated, provide a d-c source of 1,200 volts with a ripple component of less than five percent. A relay in the rectifier circuit for the screen voltage supply closes the high voltage a-c circuit to the 816's only after all of the filaments are heated.

Control Tube

In order to utilize the full sensitivity of which the photo-multiplier tube is capable, it is necessary to operate it at low anode currents. Our experience has shown (and subsequent private communications with the tube manufacturers have confirmed) that:

(1) Optimum signal-to-noise

ratio for multiplier phototubes of present day construction occurs when they are operated at about 70 to 95 volts per stage. Higher voltages give rise to spurious gas discharge pulses and overall instability.

(2) Fatigue (gradual change in anode current for steady state voltage and constant incident flux) increases rapidly with anode current. We have observed that in some tubes anode currents in excess of two to ten microamperes are accompanied by pronounced fatigue. For this reason it is desirable to operate the tube at anode currents of about one-half to one microampere. Appreciably lower operating currents are undesirable because dark current and other extraneous currents then become a significant fraction of the signal current.

By using an 807 power pentode as shown, it is possible to operate the multiplier tube under conditions which give excellent stability and sensitivity. Because the total dynode voltage varies from approximately 300 to 900 volts, the 807 plate to cathode voltage will range from about 850 to 250 volts.

The 807 control tube meets the requirement for extremely low grid current, even in the presence of very high plate voltages. Tests conducted with several 807's at 1,000 volts plate to cathode voltage show that if the screen voltage is maintained at 40 volts the grid current is less than 0.01 μa over a plate current range of 0-8 ma. Under these conditions and with a 135,000-ohm load the voltage gain of the tube is quite high, about 150, so that the control-grid to cathode voltage varies by only 4 volts over a light intensity range of 1,000 to 1.

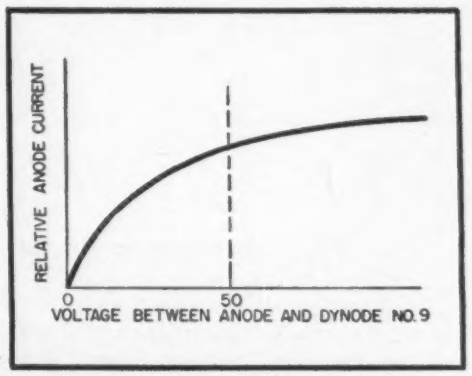


FIG. 5—Voltage versus current relationship of anode of multiplier phototube for constant dynode voltage and constant incident illumination

In order to minimize effects on calibration of variations in gain characteristics of the 807 control tube and to take full advantage of the high impedance of the multiplier anode, the control grid bias voltage is fixed at a high positive potential with respect to cathode, 60 volts, and a grid resistor of correspondingly high value is used, 100 megohms. The anode-dynode No. 9 voltage is held at a virtually constant potential of 50 volts for all values of bleeder current by the NE32 neon discharge tube. This anode voltage value is recommended by the tube manufacturers for most satisfactory results. If the NE32 tube were replaced by an extension of the bleeder resistor, anode voltage would be nearly proportional to bleeder current and calibration of the instrument would be seriously affected by changes (due to warmup and aging) in mutual conductance of the 807. This change is because the multiplier anode impedance varies to

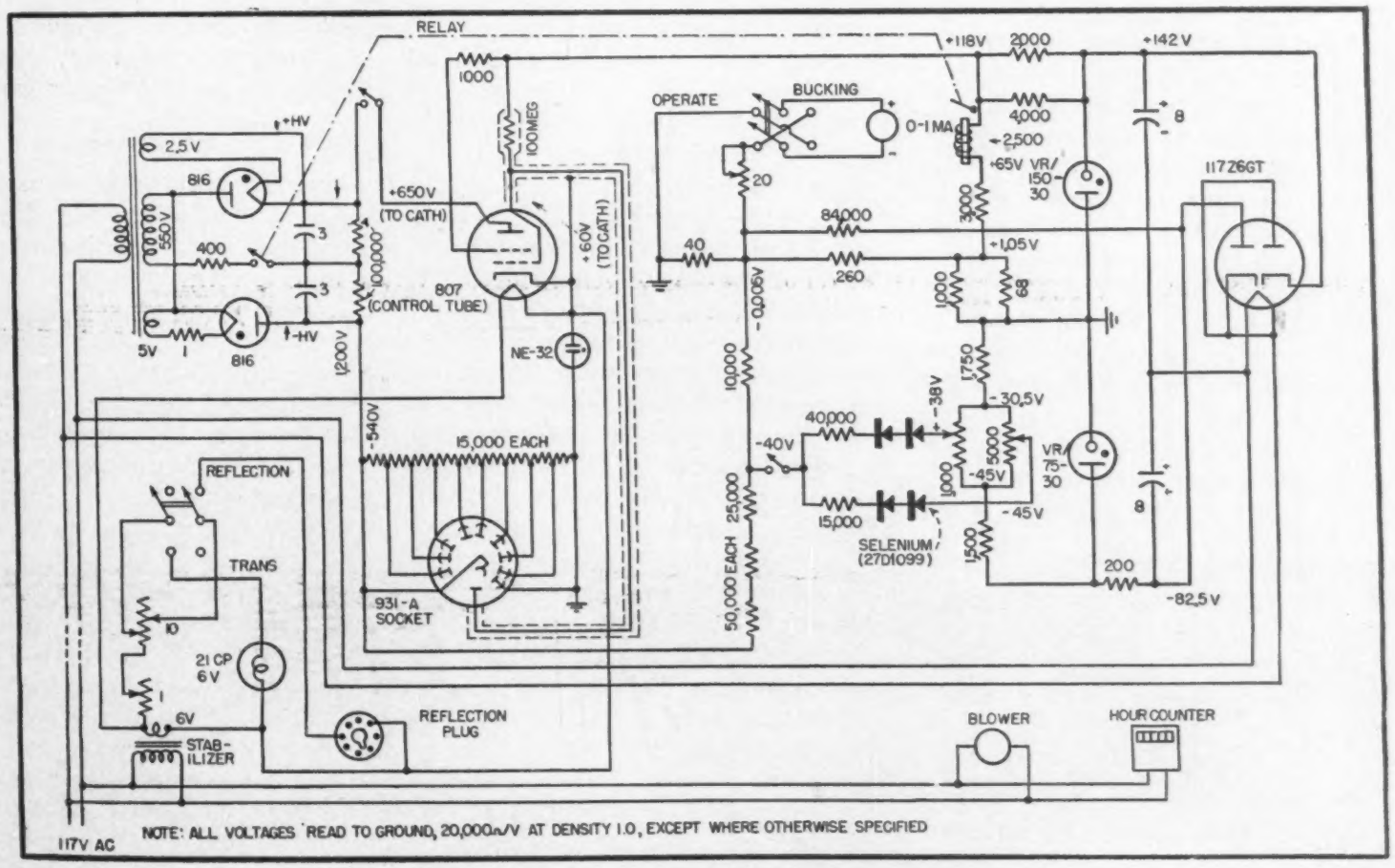


FIG. 4—Complete logarithmic multiplier phototube photometer circuit

some extent with voltage, particularly at low voltages, as is evident from the curve shown in Figure 5.

Regulated Low-Voltage Supply

A stabilized d-c supply isolated from the plate cathode circuit of the 807 is obviously necessary to provide the screen and control grid bias voltages and voltage for the compensating circuit. This additional supply was conveniently obtained by rectifying the 110-volt a-c power supply. By using a vacuum type rectifier and a relay in the bleeder circuit, automatic time delay was obtained for closing the 816 high voltage plate supply circuit. A VR150 gas stabilizer tube maintains (in combination with the NE32 tube) the constant screen and control grid supply voltages.

The output meter is a Weston model 273 0-1.0 milliammeter and is connected from ground (dynode No. 9) to the negative terminal of the power supply (cathode).

A bucking current for the output meter is derived from the positive portion of the screen voltage supply. The purpose of the bucking circuit, which gives a result equivalent to that of a suppressed zero meter, is to permit the entire scale of the meter to be used for only those dynode voltage values of interest. In the present circuit, zero meter current corresponds to about 30 volts per stage on the multiplier tube.

All commercial gaseous discharge VR tubes (type VR75, VR105, VR150 etc) exhibit a slightly positive voltage current coefficient (i.e. their terminal voltage rises with increasing tube current) and consequently they do not provide perfect stabilization as used in conventional bleeder circuits. In general, they improve the stabilization by a factor of about 10.

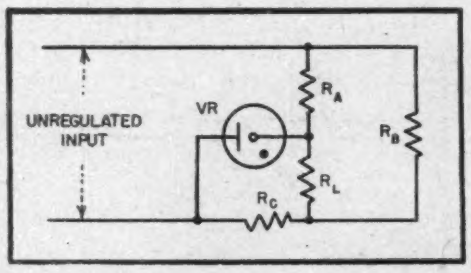


FIG. 6—Improved gaseous tube stabilizer circuit makes voltage across load resistance independent of input over a wide voltage range

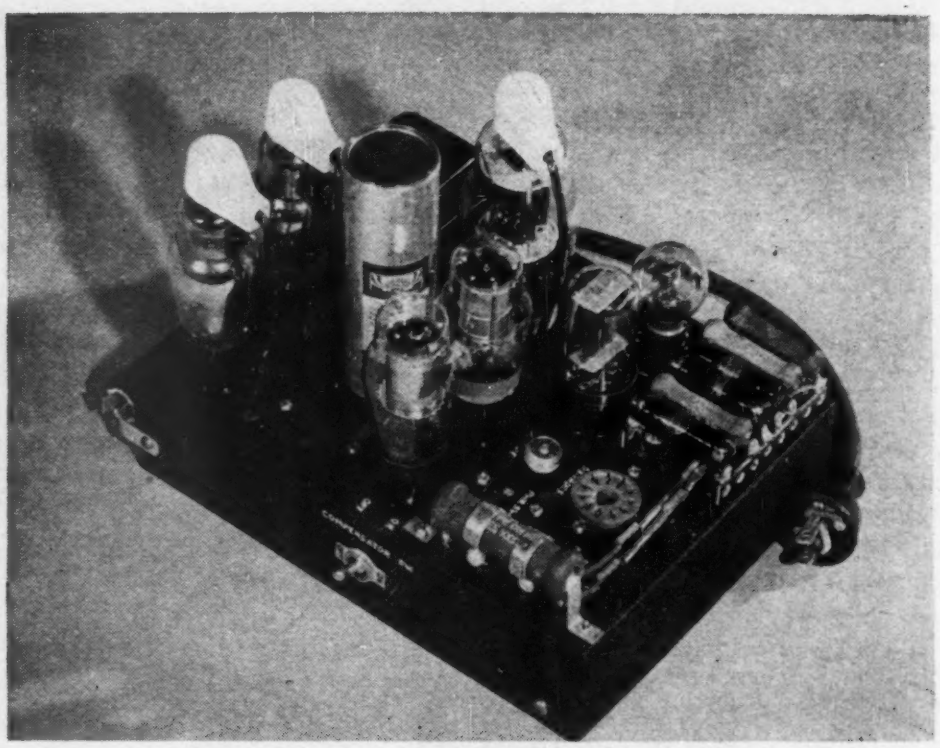


FIG. 7—Assembled power supply and control circuit of photometer

However, by using a circuit of the type illustrated in Fig. 6 the stability of load voltage may be further improved, in fact, even negative voltage-current characteristics can be obtained. In this circuit the voltage drop across the load resistor R_L will increase slightly with increasing supply voltage if R_B is infinite, due to the normal increase in voltage across the VR tube. By inserting R_B as indicated, the rate of increase in voltage drop across R_C with increasing supply voltage may be made sufficient to maintain the voltage drop across R_L at a constant value. It can be shown that if $R_E R_B = R_A R_C$ then the voltage across R_L will be independent of the supply voltage (R_E is the a-c resistance of the VR tube and is equal to the ratio of an incremental change in voltage across the VR tube to the resulting incremental change in current through the tube).

By suitable selection of the corresponding resistor values in the photometer, bucking current was compensated in such a way as to yield a minimum variation in output meter reading with changes in supply voltage.

For a range of illumination of 0.02 to 20 microlumens the corresponding 807 plate-cathode current varies from 6.6 to 2.2 ma respectively or approximately 100 to 35 volts per stage.

Figure 7 is a photograph of the power supply unit and Figure 8 shows the whole instrument, used in this case for color densitometry.

Calibration and Accuracy

The present circuit was first used to measure transmission and reflection color densities[7], and to obtain values in agreement with those derived from the use of a Schmidt and Haensch (S & H) visual polarization spectrophotometer. Therefore a number of practical specimens calibrated as to spectral density on the S & H instrument served as reference standards.

The output meter had been precalibrated to indicate density uniformly with respect to input current. As mentioned earlier, the uncompensated log F (or density) versus dynode voltage characteristic is not strictly uniform. However, it is sufficiently close so that, with the meter shunt properly adjusted, density readings from 0 to 0.8 are in satisfactory agreement with the reference densities without resort to compensation. By

adjusting the S_1 rectifier voltage tap of Fig. 3 so that the rectifier passes current only at densities of 0.8 and higher, correction is effected at densities above 0.8. In this way the instrument response is satisfactorily corrected for densities up to approximately 1.5. Similarly, by adjustment of the voltage tap for rectifier S_2 additional correction can be obtained for densities above 1.5. By proper choice of both the two rectifier voltage taps and the supplementary shunt resistors r_1 and r_2 satisfactory accuracy was obtained over the whole range (0 to 3). The corrective action is smooth and instantaneous and thereby facilitates use of the circuit in conjunction with automatic recording instruments.

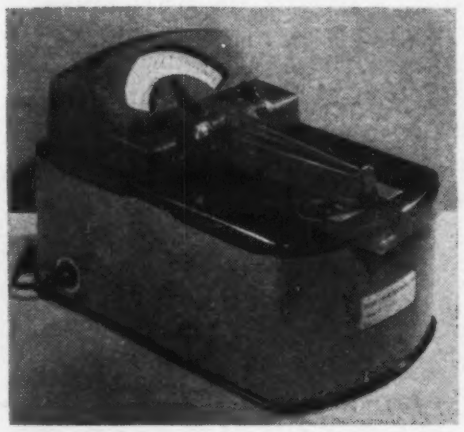


FIG. 8—Color densitometer employing the circuit described with text. Other applications are possible

Uniformity of response was checked by alternately inserting and shorting out a resistance in the lamp voltage supply circuit. This technique provided an accurately reproducible variation in light source intensity. When densities of different values (0 to 3) were interposed in the light beam, the difference in density readings produced by intermittently shorting the lamp series resistor was virtually identical over the entire scale of values. The light source modulation provided a constant percentage variation in flux and the interposition of density specimens altered the total flux level. Cumulative nonuniformity was determined by using sufficient intermittent lamp resistance to cause a log F difference of about 1.0 and incremental nonuniformity by using a low resistance which gave log F differences of only 0.05 or 0.10. If the ratio of lamp intensities for a given lamp resistor is accurately determined by any convenient method (such as the inverse square law, or by holding the dynode voltages temporarily constant and measuring the anode current values for the two conditions) the instrument can be calibrated independently, without reference to the S&H or other comparison values. The latter method of calibration may be regarded as a calibration of the slope of the log F versus current function and the former method a check on the linearity of this function.

The relationship between S&H densities and meter readings with and without compensation is shown in Figure 9.

A unique advantage of an instrument whose response is electrically uniform with respect to the log F versus current function is that it can be directly compensated for variations in light source intensity. Although the instrument described in the present paper utilizes a magnetic stabilizer in the lamp voltage circuit, this can be eliminated and the bucking current portion of the output meter circuit altered so that the proper decrease in bucking current accompanies each increase in lamp voltage. Because a given change in lamp intensity requires the same magnitude of change in bucking current to correct it regardless of the portion of the scale being used, by proper choice of circuit constants the effects of lamp intensity variations can be eliminated without resort to control of the lamp voltage.

The prototype instrument has been used for some time in the routine analysis of color products (transmission and reflection materials) and for high density measurements. The usual difficulties, well known to workers in high voltage were experienced during the early development of the instrument but it is believed that they have been eliminated in the present design. Multiplier phototubes show some individual variation with respect to stability, spectral sensitivity, and fatigue, some even exhibiting positive fatigue at one dynode voltage and negative fatigue at another, but tubes can be found which exhibit virtually zero fatigue (at the low anode current involved in this circuit) over the entire dynode voltage range of interest.

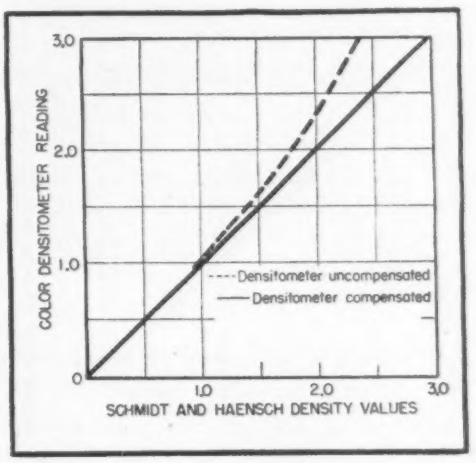


FIG. 9—Measured accuracy of color densitometer indicates improvement made by meter compensating circuit

The response of the circuit to changes in illumination is instantaneous. There is no tendency to oscillate, because of the high percentage of negative feedback, and no shunt capacitor is needed in the 807 grid circuit. The instrument is eminently suited for use in conjunction with spark recording instruments because of its insensitivity to intense high frequency radiation fields. The stability to changes in supply voltage is such that over a voltage range of 100 to 130 volts there is negligible variation in meter reading except at the highest bleeder currents (highest densities).

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(6) Patents on novel features of this circuit have been applied for.
(7) For a discussion of various types of optical density, see American Standard for Diffuse Transmission Density Z38.2.5—Appendix.

Continuously Variable Radio Remote Control

Phase-shifting properties of a resonant circuit provide automatic self-adjustment of a radio control system. Guided missiles, aircraft, satellite transmitters, and telemetering systems can be radio controlled by the stepless positioning provided

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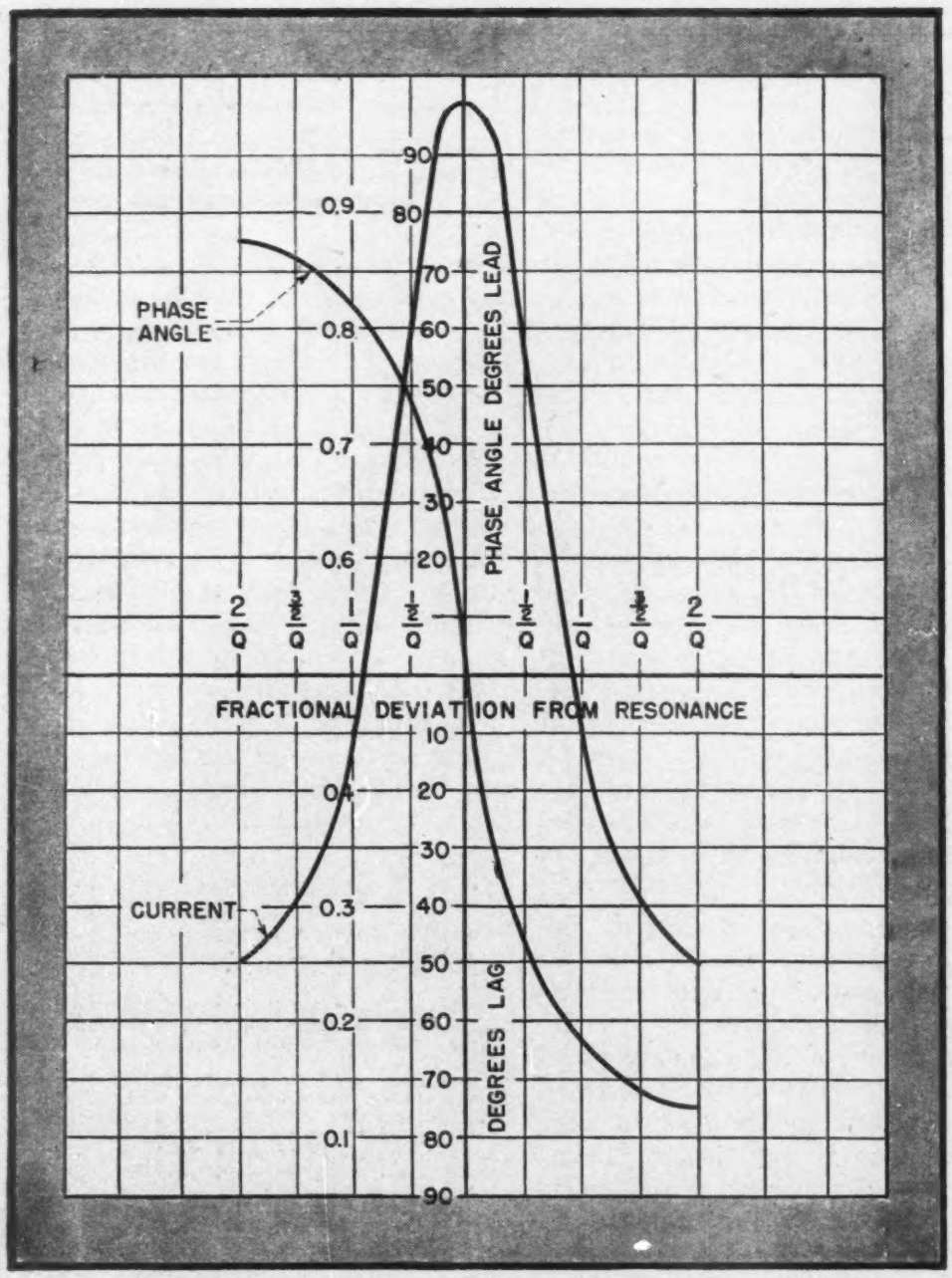


FIG. 1—Near resonance, the phase angle changes rapidly. Advantage of this characteristic is taken in design of the control system

THE HEART of any type of remotely operated device is the control method used. Its speed of response, accuracy, and ease of operation must all be satisfactory or the efficiency of the controlled object will be impaired. In some applications, such as guided missiles, the equipment for locating the missile with respect to the target may be more complicated than that for effecting control, but the control must be satisfactory to insure the success of the missile.

The basic problem of radio control may be stated as that of definitely positioning a rotating shaft by means of signals transmitted on a radio channel. Many methods have recently been developed for doing this on a step by step basis in which the controlled shaft positions itself in definite increments in response to the control signal. Some systems merely control the direction of rotation of the controlled shaft, the duration of the running determining the ultimate shaft position. In comparison to these control means, a smooth, stepless, and definite positioning device is usually preferable.

Resonant Circuit

The radio control system to be described is this latter type, and its operation is obtained from the phase-shifting properties of an electrical series resonant circuit that consists of an inductance and capacitance in series. The phase of the current flowing through a series resonant circuit is a function of the relation of the

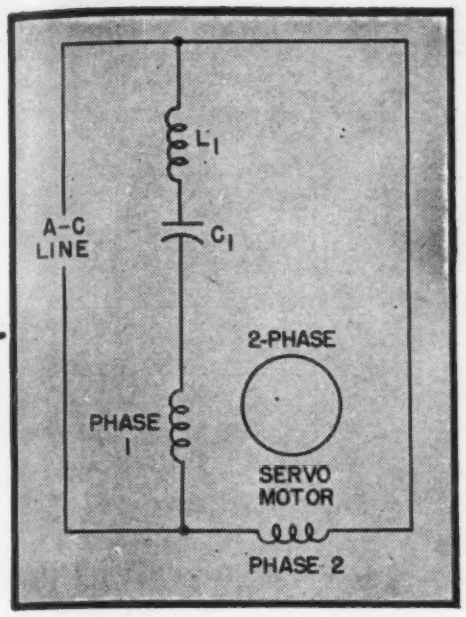


FIG. 2—The reasonant circuit formed by L_1 and C_1 controls the current flowing through the motor winding of phase 1

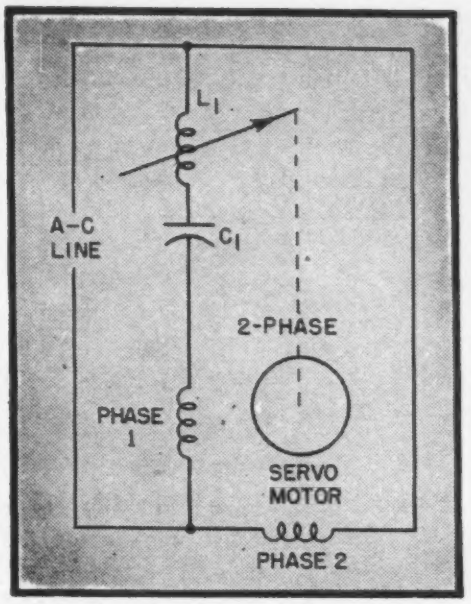


FIG. 3—Coupling the servo motor to L_1 provides automatic tuning of the motor circuit to the line frequency

resonant frequency of the circuit to the applied voltage frequency. If the resonant frequency of the circuit is the same as the line frequency, the current flowing will be in phase with the line voltage and the series resonant circuit is said to be tuned to resonance with the line.

If the line frequency is varied above or below the resonant frequency of the circuit, the phase of the current with respect to the line voltage will vary as a function of this frequency difference. Figure 1 illustrates graphically this phase-shifting property of the series resonant circuit.

The rate of change of the phase angle close to the point of resonance is particularly interesting and is the characteristic that makes possible a sensitive control system. The effective Q, or figure of merit, of the circuit elements used controls the slope near resonance, the higher the Q the greater the rate of change of phase angle. Values of Q of five to ten, which can easily be obtained with commercial inductors, will enable a very sensitive control.

Use of Servo Motor

Figure 2 shows how a circuit of this type may be used in conjunction with a phase-sensitive servo to control the speed and direction of rotation of a shaft. The phase-sensitive servo used is a conventional two-phase motor which is sensitive to small, phase angle shifts. The resonant circuit consisting of C_1 and L_1 is in series with phase 1 of the motor and so controls the phase of the current flowing through that motor winding. Phase 2 is connected directly across the line and, because it is wound to be essentially resistive, the current flowing through it is approximately in phase regardless of the line frequency.

The torque output of a two-phase motor is proportional to the product of the current in phase 1 and phase 2 and the sine of the phase angle between the two currents. Figure 1 shows that the phase of the current through phase 1 can be varied by changing the line frequency. By adjusting this frequency above and below the resonant point of L_1 and C_1, the current through phase 1 can be made to either lead or lag the current through phase 2, thus causing the servo motor to develop torque in either direction.

If the line frequency is equal to the resonant frequency of the tuned circuit, the current in phase 1 will be in phase with the line voltage and also in phase with the current through motor winding 2. This condition will result in zero torque, or a condition of equilibrium.

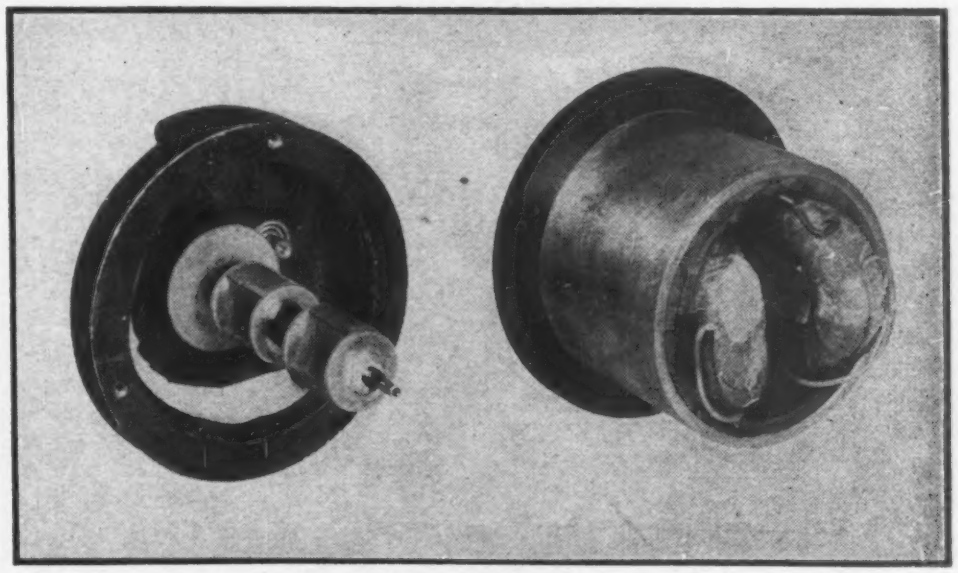
Because the line frequency can be transmitted by radio, we have a means for remotely controlling the operation of a servo motor. Thyratron tubes can be employed as phase-sensitive servos instead of a two-phase motor, to control large motors by a small amplifier.

Motor Controls Inductance

For most control applications, a control which definitely positions the controlled shaft is desired rather than one which only governs the rotation of a servo motor. Figure 3 shows how the servo motor of Fig. 2 can be coupled mechanically to a variable L_1. If the motor is phased correctly, it will automatically tune the circuit L_1 and C_1 to resonance with the applied voltage by varying the value of L_1. The position of the shaft which controls the value of L_1 is a function of the value of L_1 and therefore of the line frequency, because L_1 is automatically adjusted to keep circuits tuned to line frequency.

In appearance, the variable inductance resembles a motor. Figure 4 shows the construction of a double variable inductance unit. There are no windings on the rotor, and conse-

FIG. 4—Construction of a double variable inductance. A single unit, such as L_1 of Fig. 3, would have one rotor



quently no brushes or slip rings to wear and deteriorate. The inductance variation is linear for a little more than sixty degrees rotation of the shaft.

Figure 5 shows an inductance transmitter on the right, and a position receiver consisting of an inductance and two-phase servo motor and the necessary gearing between the two. The gear sector couples the inductance shaft which is positioned by the line frequency to the load to be controlled.

Values of Circuit

A range of line frequency is necessary to position the shaft of L_1 throughout its range of some sixty degrees. The magnitude of this frequency band is determined by the inductance value and that of the tuning capacitor. Typical calibrations are shown in Fig. 6 and 7.

Referring to Fig. 6, control throughout sixty degrees of inductance shaft rotation requires a frequency band of from 50 to 80 cycles. In this example the inductance value is 20.5 henrys and the tuning capacitor 0.283 μf. The inductance of the motor winding in series with the resonant circuit is 5.65 henrys.

The control whose calibration is shown in Fig. 7 was adjusted for a different frequency band, seventy degrees of motion being controlled by a frequency variation from 135 to 198 cycles. The value of inductance is 28.2 henrys and the tuning capacitor is 0.033 μf.

Both of these controls could be transmitted on one carrier requiring an audio band of from 50 to 198 cycles. More controls at higher frequency bands could be added. For a large number of controls on one carrier, though, a subcarrier frequency system should be employed which would enable a practically unlimited number of controls especially if microwave transmission is employed. The carrier with the numerous subcarriers could be beamed to the controlled unit along with any other necessary intelligence.

Torque-error Data

The relationship between the torque generated by this system of radio control and the error between the control resonant frequency and the frequency of the voltage applied to the control is shown by the graph of Fig. 8. The solid lines illustrate the motor torque for different applied frequencies for three settings of the control. The graph covers a band of 50 to 75 cycles with the control set at 52, 60, and 73 cycles. These control setting frequencies are the frequencies to which L_1 and C_1 are set. Zero torque is not usually obtained when these frequencies are impressed upon the control due to slight phase shifts in phase 2 with changes in frequency.

The dotted lines show the motor torque for various constant displacements between the control setting and applied frequency throughout the bands. For example, it may be seen that for a one-percent deviation, substantially 0.025 inch ounce can be obtained at any place in the band. Five-percent deviation increases this torque to 0.13 inch ounce.

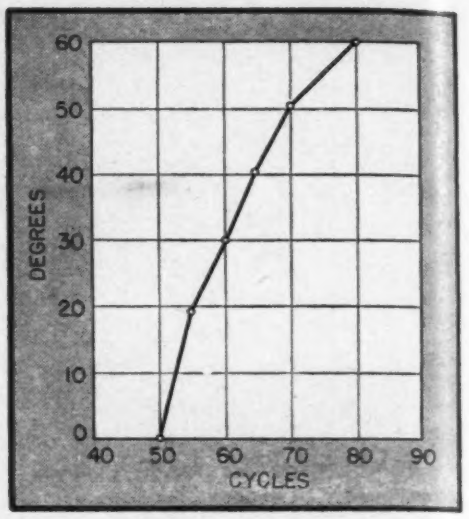
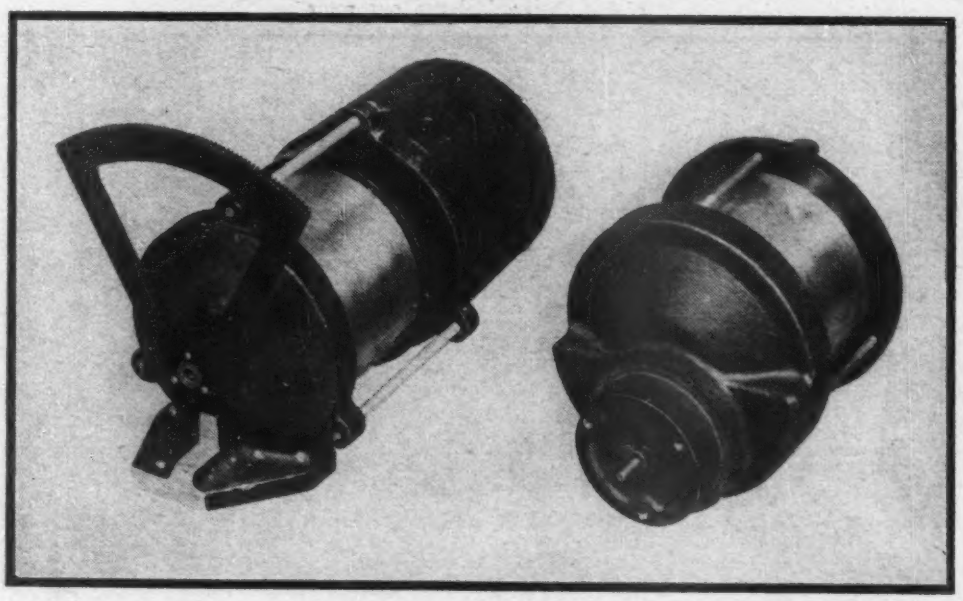


FIG. 6—Operation in the frequency range from 50 to 80 cycles provides 60 degrees of rotation of the inductance shaft

FIG. 5—At left, a two-phase motor and a variable inductance are combined in one unit. A separate variable inductance unit is shown at right



From these charts the operation of a system of this type can be easily predicted. These figures are typical only of the control constructed and more or less torque could be obtained by suitable design. The torque output shown is that obtained at the motor shaft and gearing to bring this up to the required amount must be employed.

The tuned circuits of this radio control method are natural filters and help to minimize any effects due to harmonic content of the applied frequency. However it is best to keep the harmonic content low. If trouble were experienced from this source, additional harmonic filters could easily be included. Phase shifts in the filters would not affect the operation.

Complete System

Figure 9 is a schematic of a complete single-channel control system which has been designed to permit very close tracking between the position of the transmitting inductance shaft and the position of the controlled inductance shaft. The transmitting inductance is electrically identical to the controlled inductance and, the tuning capacitors are also equal; thus $L_1 = L_2$ and $C_1 = C_2$.

The radio position transmitter is designed to operate in conjunction with a standard type of audio-frequency oscillator and adjusts the tuning control of the oscillator until its output frequency is equal to the resonant frequency of the circuit L_1C_1. The resonant frequency of this circuit is adjusted to the desired value

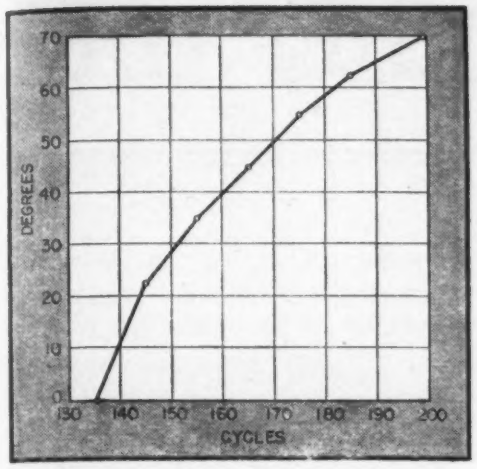


FIG. 7—Seventy degrees of rotary motion were obtained by using frequencies between 135 and 198 cycles

by setting L_1, manually or otherwise. The oscillator frequency is then transmitted by radio to the radio position receiver.

The radio position receiver tunes itself to the oscillator frequency, and, because the tuned circuit constants are identical elements, L_2 is driven by the servo motor to a position corresponding to the position of L_1, effecting the desired control.

The detailed operation is as follows: First, L_1 is adjusted, setting the resonant circuit L_1C_1 to a definite resonant frequency. The audio oscillator output is impressed across the radio position transmitter circuit which is like that shown in Fig. 3, except that the servo motor adjusts the audio oscillator frequency instead of the inductance L_1. Thus the servo motor tunes the oscillator to the resonant frequency of L_1C_1 instead of adjusting L_1 to tune L_1C_1 to the oscillator frequency.

The radio position receiver is identical to Fig. 3, the servo motor adjusting L_2 to tune L_2C_2 to the oscillator frequency which has been transmitted by radio. The control shafts of inductances L_1 and L_2 are thereby synchronized.

The purpose of this circuit is twofold. It permits a linear response between the transmitting and controlled shafts which makes for ease of control in many applications. It also automatically compensates for frequency drift in the audio oscillator due to temperature or supply voltage changes because the servo motor will retune the oscillator should frequency variation occur.

If a subcarrier system were employed, the desired number of controls would be set up and each oscillator output would modulate a subcarrier. The subcarriers would be transmitted by a high-frequency carrier to the controlled device. The frequency of the carrier would be determined by the number of subcarriers desired.

Small, two-phase, servo motors operating in the type of circuits shown will develop adequate power to set the controls of an automatic pilot in any aircraft to be remotely guided. More power, to adjust the aircraft control surfaces directly, could be easily obtained by having the two-phase, servo motor operate a hydraulic pilot valve or through the use of thyratron tubes. Other interesting variations can be worked out.

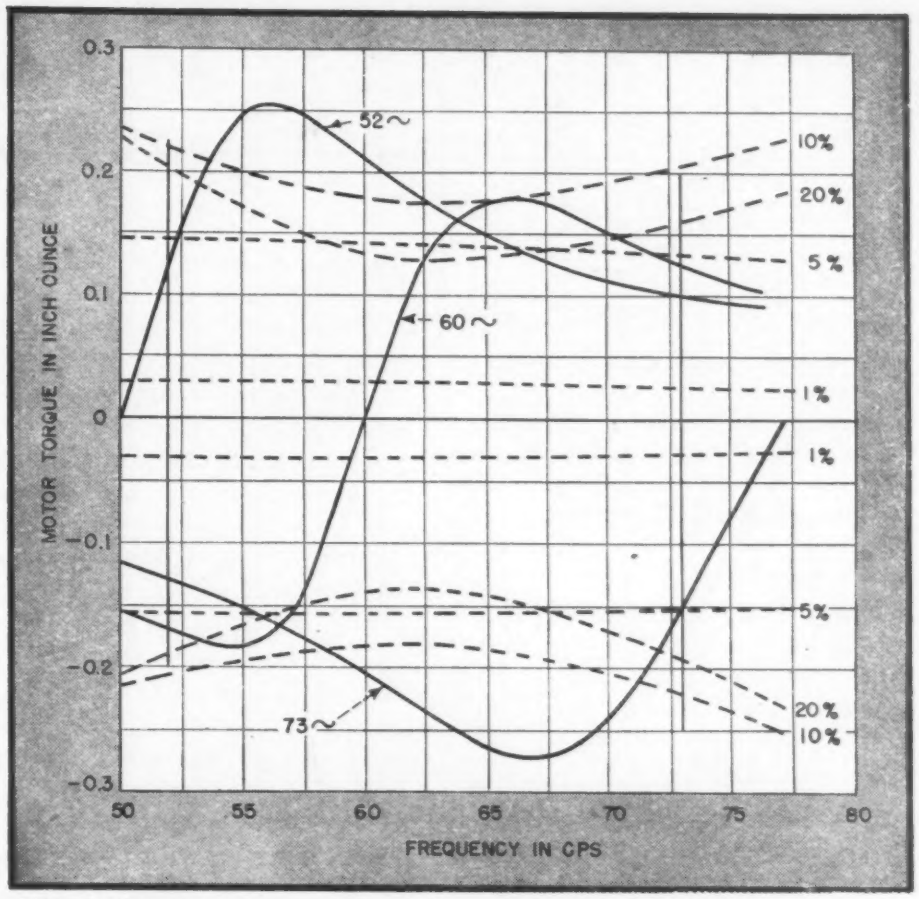


FIG. 8—Torque response curves of the control when set for resonance at frequencies of 52, 60, and 73 cycles. The solid lines indicate the resonant frequency constant; the dashed lines show the constant deviation in percent

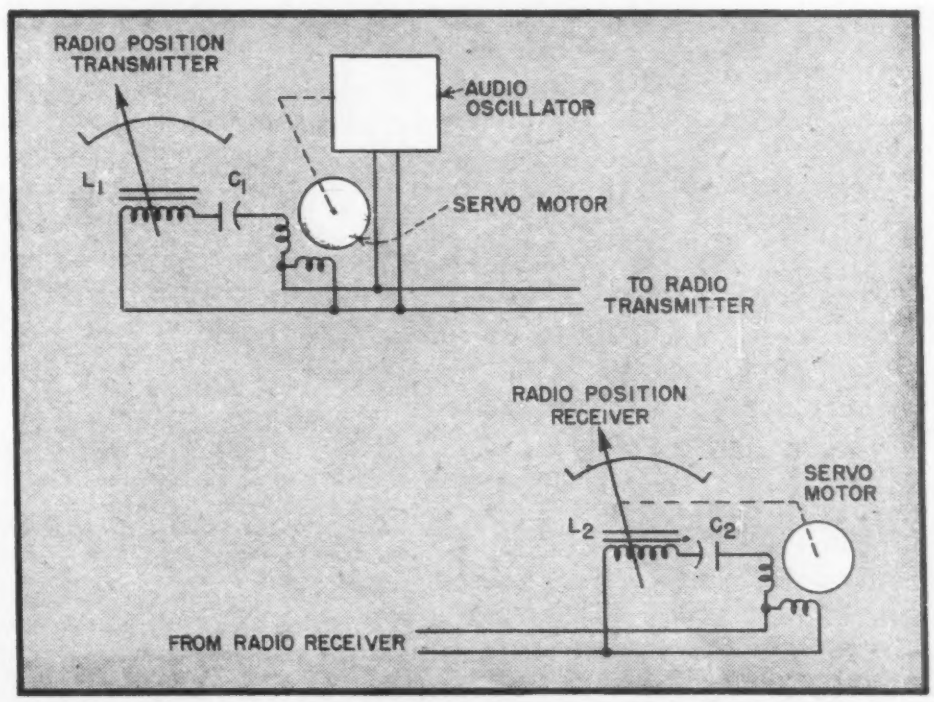


FIG. 9—Essential units of the receiver and transmitter of the radio control system

NOISE and

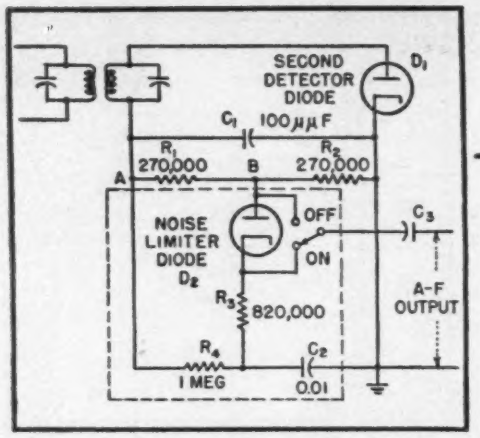


FIG. 1—Simple series limiter, requiring only the four additional components inside the dash-dash rectangle

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LIMITERS, as the name implies, are restrictive devices. The limiter circuits discussed in this report are curative means designed to mitigate the effects of undesired electrical disturbances of an impulse nature, such as static, ignition noise, and radar signals, on the output of radio receivers designed particularly for amplitude-modulated communications use.

Preventive means operating directly in the antenna circuit have not as yet been developed with any considerable degree of success. The circuits described below center at or near the final detector in a receiver, and the best of them, when properly designed and operated, can provide very considerable assistance in reception through many forms of noise.

Limiters are divided into three groups: (1) instantaneous noise-peak limiters, whose primary usefulness is in modulated-wave (mcw) reception such as speech and music; (2) output limiters, useful mainly for continuous-wave (c-w) reception, such as telegraph signals; (3) circuits not falling directly into the first two groups.

Instantaneous Noise-Peak Limiters

Limiters of this general group are actually operative only when the instantaneous value of the carrier exceeds some reference level, which may be a d-c bias voltage controlled from the front panel of the receiver or, better, the average value of the rectified carrier itself as it appears across the final detector load.

Essentially, an instantaneous noise-peak limiter usually involves two circuits, one having a time-constant corresponding to the usual detector load circuit, and the other having a much longer time-constant. The time-constant differential of these two circuits is responsible in large part for the successful operation of the limiter.

Most of the instantaneous limiters to be described are half-wave devices and operate on the modulation envelope resulting from rectification of the positive half-cycles of r-f input to the detector. The usual form of half-wave diode detector does not respond substantially to the negative half-cycles of signal, and therefore suppresses also the negative half-cycle of r-f noise peak where it exceeds the equivalent of 100 percent modulation of the desired carrier. Full-wave limiters generally do not provide a substantial improvement when applied to such detector circuits on mcw operation, unless considerable clipping of the desired modulation is tolerable.

Series Noise-Peak Limiters

The most useful and successful of the instantaneous group are series noise-peak limiters. In contrast to others of this group, which have not been very effective on the longer wave-trains resulting from impulse excitation in receivers operating below about 10 mc, series-type limiters have been highly effective in receivers covering the signal range from 15 kc to over 400 mc. They also satisfy one general requirement for limiters intended for mcw use by not causing a degree of distortion which would affect the intelligibility of voice signals or seriously impair the quality of music, when the usual average values of carrier modulation are employed at the transmitters.

In addition, series limiters require very few components over those normally found in the usual half-wave diode detector, and are easily adaptable to automatic threshold biasing by the rectified voltage of such a detector. These limiters have also been found useful for c-w reception if care is taken to provide the proper value of beating or heterodyne voltage at the final detector.

The second and final part of this paper will take up six basic versions of r-f and a-f output limiters, an f-m discriminator for a-m limiting and a number of special types of limiters, then give characteristics of crystal and thermionic diodes for limiting and make recommendations of the best limiter choices for mcw operation and for c-w operation.

Simple Series Limiter

Figure 1 shows the simplest form of series limiter, widely used in Navy shipboard receivers. It requires only one fixed capacitor, two fixed resistors, and an independent diode in addition to the normal components of a diode second detector. No front-panel control of threshold for varying carrier levels is required, threshold bias being automatic in the sense that it is directly derived from the rectified carrier. Its operation can be briefly described as follows:

Assume a rectified d-c potential of 10 volts developed across R_1 and R_2 in Fig. 1 by a constant carrier. The cathode of the limiter diode is then initially at about −10 volts with respect to ground because of its connection to point A through R_3 and R_4, while the limiter plate is at about −5 volts to ground. The plate is thus momentarily 5 volts positive with respect to the cathode and the limiter diode becomes conductive, its resistance being fairly

OUTPUT LIMITERS

Part I

Comprehensive two-part survey of instantaneous noise-peak and output limiters for a-m communications receivers. Eleven noise limiter circuits are presented in this part with representative values of components, analysis of operation, and conclusions as to usefulness

low compared to the other resistance values in the circuit. Output capacitor C_3 is thereby connected through the conductive diode to junction B, so that a constant modulated r-f carrier input provides a-f output. This output is about 45 percent of what it could be without the limiter, but generally this reduction is of little significance since it usually affects only the reserve gain and not the sensitivity of the receiver.

Under the above conditions, capacitor C_3 is charged through

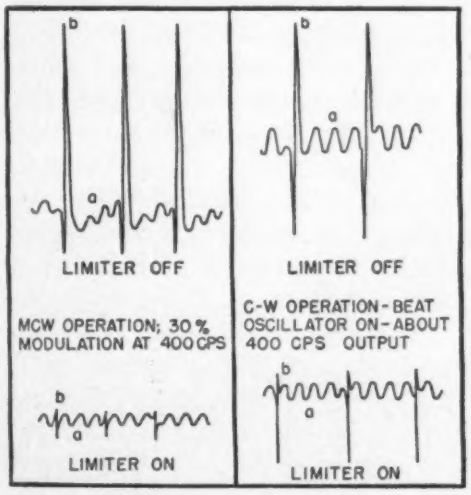


FIG. 2—Oscilloscope tracings of audio output of receiver, illustrating noise suppression of simple series limiter. Signal input to receiver is 80 microvolts, and avc is off

1-megohm resistor R_4 to a potential of about −7 volts. Any appreciable change in this potential would require about 0.01 second, due to the time-constant of R_4C_2. The time-constant of $(R_1 + R_2)C_1$ is, however, only about 50 microseconds, so that the potential at the limiter diode plate can change in about 1/200th of the time required for its cathode to assume a new potential. Therefore, if a noise potential of perhaps 100 volts suddenly appears across $R_1 + R_2$ and brings the plate of the limiter diode to −50 volts from ground potential, the diode plate becomes about 43 volts more negative than its cathode and the diode stops conducting. This in effect disconnects output capacitor C_3 from point B, and the a-f amplifier has no appreciable input for the duration of the noise modulation. By the time that the cathode of the limiter diode has assumed an effectively more negative potential, the noise pulse will usually have decayed and the limiter diode will have become conductive again, restoring the a-f input to the audio amplifier.

With this limiter, appreciable distortion can be seen on an oscilloscope only above approximately 40 percent modulation. In listening tests involving both speech and music, most personnel have found it extremely difficult to detect distortion by ear on transmission maintaining an average modulation level of between 30 and 40 percent, a condition commonly encountered. With the circuit constants shown in Fig. 1, the time-constant of recovery from surge input is very satisfactory, an item of importance, especially in shipboard receivers.

It should be noted that the modulation threshold value given above applies to distortion of only that half of the audio envelope appearing across the detector load which corresponds to increasing rectified current, the other half-cycle being unaffected with a half-wave limiter. This is likewise true of most of the limiters described below.

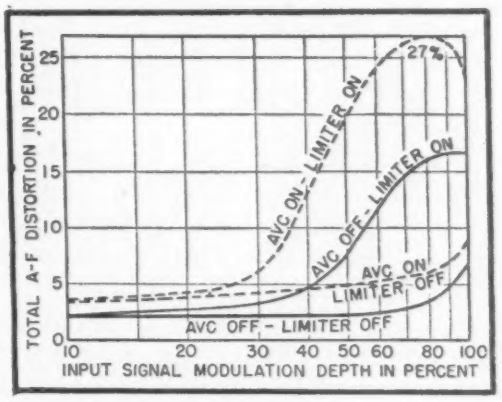


FIG. 3—Modulation distortion curves as measured at output of typical communications receiver using simple series limiter. The avc-off curves are substantially the same as for weak-signal avc-on operation. Signal input frequency is 4,000 kc, a-f output frequency is 1,000 cycles, and signal input level is 1,000 microvolts

Oscilloscope tracings illustrating the operation of the simple series limiter on both mcw and c-w signals in a typical receiver appear in Fig. 2. On c-w, the beat oscillator acts to produce operation of the limiter similar to that with a very low percentage of desired signal modulation at the detector.

Modulation distortion under various conditions of mcw operation is indicated by the curves in Fig. 3. The change in threshold of limiter action between weak and strong signals is particularly evident.

Operation of the series limiter on c-w reception may be improved by the incorporation of some additional degree of r-f limiting in the i-f (or r-f) amplifier immediately preceding the final detector. This can take the form of an added grid leak and capacitor between the control grid and the i-f transformer of this amplifier stage. The resultant better i-f limiting will allow the use of a lower beat oscillator

injection voltage to the detector without abrogating resonant overload performance, a condition favoring good operation of the limiter following the detector.

Series-Type Noise Limiter With Threshold Adjustment

With a potentiometer substituted for fixed resistor R_1 in the circuit of Fig. 1, the limiter threshold can be varied from about 65 percent modulation down to substantially zero percent (on half the modulation cycle). This control varies the d-c bias due to the rectified carrier at the cathode of the limiter diode, which bias determines the limiting threshold.

The modified circuit, shown in Fig. 4, may also include an additional diode. This is shunted across resistor R_3 to buck the internal (thermionic) potential of the limiter diode, as this residual voltage reduces the effectiveness of the limiter at low carrier levels by raising the limiting threshold in terms of modulation percentage. The voltage built up across R_3 due to rectified direct current from the detector will, together with the time-constant of C_3 and the grid resistor in the first a-f stage, tend to maintain this additional diode biased to cutoff, except on weak signals. The price paid for this improvement in weak-signal limiting, however, is generally a considerable increase in audio distortion at all useful levels. Making the time-constant of C_3 and the audio amplifier grid leak equal to that of R_4C_2 will assist in keeping this increase in distortion to a minimum.

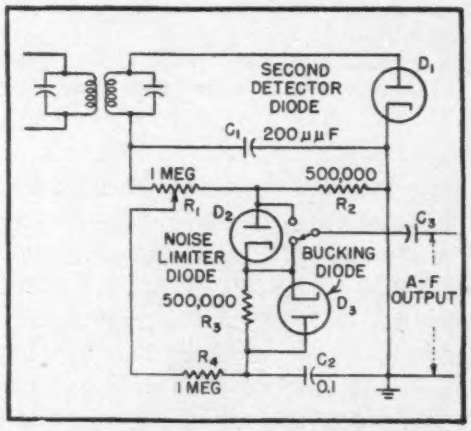


FIG. 4—Series-type noise limiter with threshold adjustment so that limiter operation can be set to start anywhere in range from 0 to 65 percent modulation

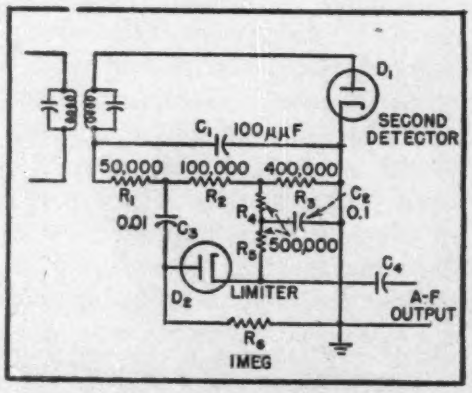


FIG. 5—Low-loss series limiter, requiring three more components than the simplest version in Fig. 1

Low-Loss Series-Type Noise Limiter

The reversal of cathode and plate connections of the limiter diode in the variation of the series-type limiter shown in Fig. 5 necessitates the use of two more resistors and a capacitor (over those required by the simplest form) to provide the required biasing and *RC* delay circuits for the diode elements. It has, however, the advantage of providing the a-f amplifier with a higher percentage of the a-f voltage appearing across the detector diode load, as contrasted with the circuit of Fig. 1. For a comparable degree of modulation distortion, this improved transfer of a-f voltage will amount to about 2 or 3 db, which is usually not of great importance unless the receiver is deficient in reserve gain.

The cathode of limiter diode D_2 is biased negative relative to its plate by connection to the junction of detector-load resistors R_2 and R_3 through resistors R_4 and R_5. R_4C_2 provides a long time-constant circuit similar to R_1C_2 in Fig. 1 while R_5 serves as the cathode load resistor across which the limiter output voltage is developed in a manner similar to R_3 in Fig. 1. Capacitor C_3 provides a-f coupling to the plate of D_2 for the detector audio output voltage appearing between the junction of R_1 and R_2 and ground. Resistor R_1 serves only as an r-f filter element. The action of this circuit in limiting peaks of noise or other modulation is identical to the circuit shown in Fig. 1, the plate of D_2 being free to follow variations in detector a-f output voltage, while the cathode circuit is held by the longer time constant of R_4C_2.

Hum is one of the serious difficulties in any system wherein audio signals are taken from a relatively high value of resistance load located in the cathode circuit of an a-c heated vacuum tube. The heater-cathode capacitance of the most widely used receiver tubes will be on the order of 5 to 10 $\mu\mu$f, which at 60 cps presents a capacitive reactance of 250 to 500 megohms. With a resistive load between cathode and ground of perhaps 0.5 megohm, about 0.1 percent of the heater-to-ground potential will appear across the cathode resistor. This would be about 6 millivolts with a 6.3-volt heater.

Hum Reduction in Simple Series Limiter

When using the simple series limiter circuit of Fig. 1 with a 6H6 duodiode, the hum voltage appearing across R_3 may be approximately halved by grounding that end of the heater which is closer to the cathode element used for the limiter diode, since in the 6H6 the individual diode heater windings are in series. With even fairly high-gain a-f amplifiers, however, the hum will usually be troublesome even though this precaution is taken.

The circuit arrangement in Fig. 6 has been found highly satisfactory for further reducing hum from the series limiter. The reduction obtained will generally be on the order of 20 db with normal commercial variations in tubes and other components. The cathode resistor of the a-f amplifier following the limiter will not be bypassed to ground, resulting in some decrease in the gain otherwise obtained from this audio stage, due to degeneration. Two additional capacitors and a resistor are required over those needed for a normal a-f amplifier input system with unbypassed cathode.

The equivalent circuit is that of a bridge, with e_h as the limiter diode heater voltage (normally grounded on one side in most receivers) and C_{hk} as the heater-cathode capacitance. R_3 and C_2 form another arm of the bridge and are shunted by the equivalent resistance R_e, which is a composite of R_1, R_2, R_4, the effective resistance of D_1, etc. R_7 is the cathode bias resistor for a-f amplifier tube V_4. The

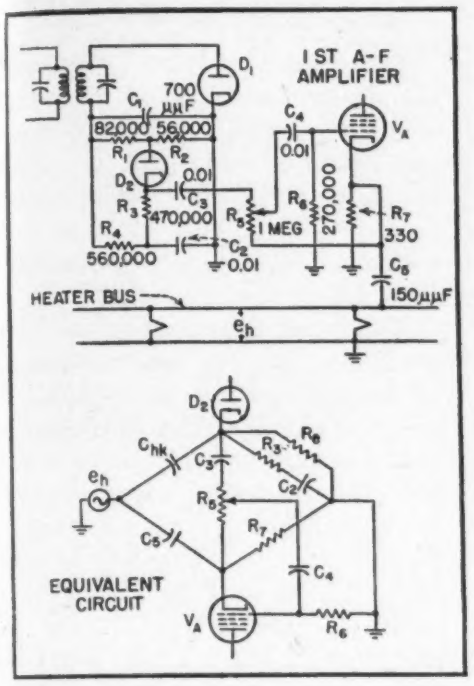


FIG. 6—Hum-reduction version of simple series limiter, with equivalent circuit arranged to show bridge configuration

bridge configuration is completed by capacitor C_5, which is connected between the ungrounded side of the heater supply and the cathode of V_A. Fortunately, the value of C_5 with the usual limiter circuit values is quite low; in the circuit shown it is only 150 $\mu\mu$f. It should be noted that this hum-bridge scheme allows normal location and operation of the a-f gain control R_5, even to the extent that despite unbypassed cathode resistor R_7, the gain control can reduce the input to V_A substantially to zero, since its low end returns to the cathode of V_A. It should also be noted that, if a LIMITER ON-OFF switch is used, two different values of C_5 will be required, due to slight changes in bridge configuration when switching from the cathode to the plate of the limiter diode.

Balanced-Detector Noise Limiter

The circuit of Fig. 7 functions as a balanced bridge arrangement for detector voltages above the limiting threshold, with unbalance being maintained at all other times. It must be adjusted manually for each carrier level, but automatic operation can be achieved by adding another diode, as in Fig. 8.

When the contact arm of R_6 in Fig. 7 is at the grounded end of R_6 and R_4 is set equal to R_2 (47,000 ohms), R_1, R_2, R_3, and R_4 form a balanced resistance-bridge circuit which is fed from the i-f output through the second detector and noise limiter diodes. If both diodes rectify in phase and their loads are equal, the a-f output across R_5 is essentially zero. When the limiter diode is made inoperative by adjusting R_6 to bias its cathode with a positive d-c voltage, the bridge becomes unbalanced and a-f output is obtained when a constant modulated carrier input is present. If, now, a noise peak arrives that exceeds the limiter diode bias, the bridge will be rebalanced and substantially no a-f output will be obtained for that part of the noise peak during which it exceeds the diode bias voltage.

The limiter normally is initially balanced by adjusting R_4, and is thereafter adjusted for each carrier level and desired modulation threshold only by means of front-panel control R_6. Adjustment of R_6, however, disturbs the balance of the bridge by varying the resistance of one arm, hence it may be desirable to gang a variable resistor with R_6 so as to hold its equivalent resistance constant. For most effective operation, the time-constant of $(R_1 + R_2)C_1$ should equal that of $(R_3 + R_4)C_2$ for all settings of R_6, and the capacitances of the two diodes should be equal.

During tests at U. S. broadcast frequencies, no improvement in receiver performance was discernible with this limiter, improvement becoming noticeable only above about 10 mc and only on ignition-pulse types of interference. The need for adjusting to changing carrier values makes this circuit practically useless on fading signals, unless limiter control settings such as would cause serious distortion are tolerable. No appreciable limiting was obtained on c-w reception employing a beat oscillator.

Automatic Balanced-Detector Noise Limiter

By adding another diode circuit to the arrangement of Fig. 7, automatic operation is obtained, eliminating adjustment of a balancing potentiometer with each change in carrier level. The additional diode is operated from a tertiary winding on the final i-f transformer, as shown in Fig. 8. This diode rectifies the i-f carrier to provide a d-c bias of about twice the mean rectified voltage furnished by the detector diode, so that limiting does not take place on modulation depths below about 100 percent. The bias voltage is applied to R_3 at the point where R_6 (Fig. 7) introduces the bias in the manually controlled circuit. The cathode delay bias on the noise limiter diode is thus maintained automatically at a substantially constant ratio with respect to the carrier input. The depth of modulation at which audio distortion begins is mainly determined by the ratio of the rectified voltage supplied by the automatic biasing diode to that supplied by the detector diode. The limitations in performance of this circuit, however, are otherwise similar to those applying to Fig. 7.

Balancing-Type Noise Limiter

The balancing (or bucking) effect of a diode shunted across the second detector with reversed polarity is used in the circuit of Fig. 9. When the limiting threshold is passed, as on noise peaks, the variations in limiter diode current oppose the normal demodulation current in the second detector.

Assume that an unmodulated car-

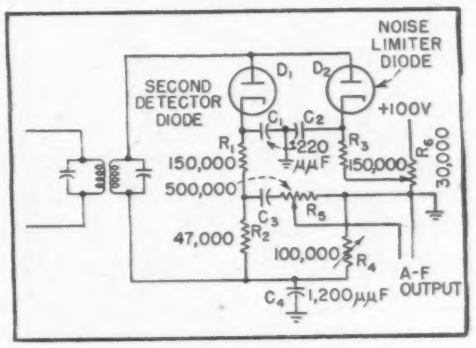


FIG. 7—Balanced-detector noise limiter

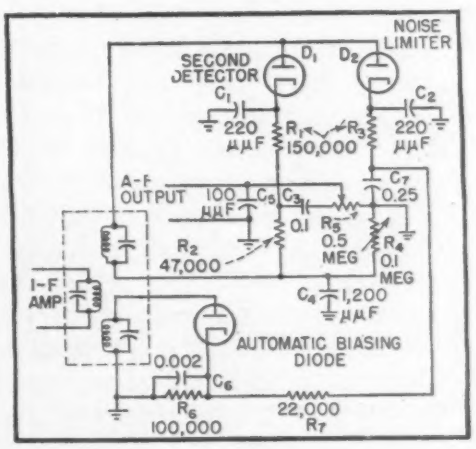


FIG. 8—Automatic balanced-detector noise limiter

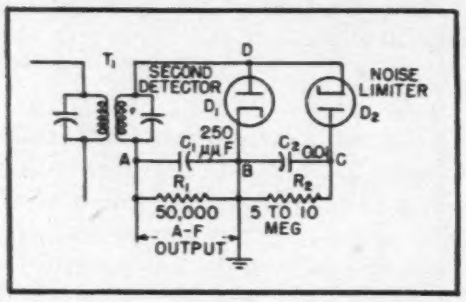


FIG. 9—Balancing-type noise limiter

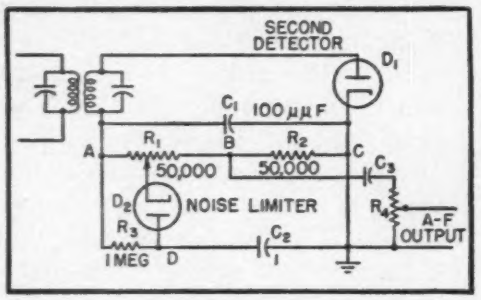


FIG. 11—Diode shunt-type noise limiter

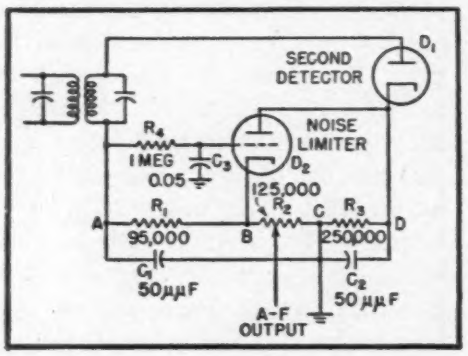


FIG. 10—Triode shunt-type noise limiter

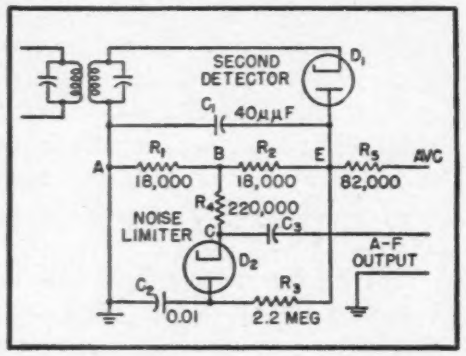


FIG. 12—Modified shunt noise limiter

rier produces a rectified potential of 10 volts across second detector diode load R_1, making point A 10 volts negative with respect to ground. Then, on positive peaks of carrier input, point D will be close to ground potential, because point A remains relatively constant over an r-f cycle and the 10-volt positive r-f peak across the i-f transformer secondary acts to cancel the negative 10 volts at A. On negative peaks, point D will therefore be about −20 volts with respect to ground.

The voltage impressed across the noise limiter diode in series with R_2 will then vary between substantially zero and −20 volts at an r-f rate. This builds up a potential of about −20 volts across capacitor C_2, thereby biasing the limiter diode plate 20 volts negative with respect to ground. The net effect is that the second detector diode is shunted by a high impedance, between about 2.5 to 5 megohms for the value of R_2 shown, until such a time as the i-f input voltage increases substantially above the 10-volt value, as on a noise peak or with modulation of the carrier. When this occurs, the limiter diode becomes conductive for all portions of the modulated wave having an instantaneous value in excess of 10 volts negative. It should be noted that the audio voltage appearing across R_1C_1 is added to the instantaneous negative voltage peaks appearing across the secondary of T_1, in addition to the mean value of rectified carrier voltage across R_1. Since the time-constant of R_2C_2 is long, about 0.05 to 0.1 second, C_2 will serve mainly as a coupling capacitance to R_1 as regards a-f variations. These variations, being of opposite polarity to those across R_1, will tend to cancel the latter on half the audio cycle. The magnitude of the cancellation effect will depend on the impedance of the limiter diode when conducting, which in turn will depend on the values of the impressed voltages and R_2, so that better cancellation will in general be obtained as R_2 approaches R_1 in value. This would necessitate increase of C_2 to a large value to maintain the time-constant of R_2C_2 at the desired magnitude, and would increase the a-c loading across R_1 as regards audio output, seriously affecting modulation distortion except with the limiter disabled.

The modulation distortion of this type of limiter is quite high, even on relatively low modulation depths, with effective limiting of noise peaks. Although the distortion can be reduced by various expedients, perhaps the most attractive feature of the circuit is its ability to provide about twice the normally obtainable avc voltage when the d-c potential across R_2 is utilized.

Triode Shunt-Type Noise Limiter

The circuit of Fig. 10 employs the plate resistance of a triode shunted across a portion of the second detector diode load, the magnitude of the shunt resistance being controlled by the grid and plate voltages, which act in conjunction with differential time-constants.

Assuming a carrier input that produces a total rectified voltage of 10 volts across the diode load (between A and D), potentials relative to the second detector cathode will be −10 volts for A, about −8 volts for B, and about −5.3 volts for C. The triode plate is thus 8 volts positive with respect to its cathode, while its control grid (connected to A through R_4) is 2 volts negative. For a triode with a μ of 20, this produces plate current cutoff, so that the triode plate resistance is high and has little shunting effect on second detector load resistor R_1 and R_2. Now if a 100-volt noise pulse suddenly appears between points A and D, the triode plate-cathode voltage rises to 80 volts relatively long before the grid potential can change, since the plate circuit time-constant is about 12 microseconds while that of the grid circuit is about 50 milliseconds. The triode then becomes conductive and shunts section B-D of the detector load for the duration of the noise pulse, thereby reducing the audio output from the detector. The noise disturbance should subside before the control grid swings sufficiently negative to stop this limiting action.

The percentage of modulation at which audio distortion due to the limiter appears depends upon the type of triode used, the relative values of R_1, R_2, and R_3, the time-constants involved, and the absolute carrier level. The higher carrier levels produce no distortion (and no limiting). Serious distortion, however, has been observed for modulation as low as 10 percent with low signal levels. Effective limiting action is restricted to a narrow range of carrier input levels, generally being evident above 10 mc in carrier frequency.

Simple Diode Shunt-Type Noise Limiter

In Fig. 11 is shown the simplest limiter of them all, requiring only

an additional resistor and a capacitor, along with an independent diode.

Here R_1 and R_2, bypassed by C_1, provide a detector diode load with a time-constant of about 10 microseconds, to which is connected the cathode of the noise limiter diode. The limiter plate circuit time-constant is 1 second, so that the limiter diode conducts and shunts the detector diode load on noise (and modulation) peaks. During such peaks, the a-f output of the detector is reduced by an amount which depends on the value of R_3 plus the portion of R_1 between point A and the limiter cathode, the position of the variable contact on R_1, and the noise peak voltage. The depth of modulation above which distortion begins is determined by the relative values of R_1 and R_2 and by the setting of R_1. The performance of this limiter was not very good, some improvement being evident on pulse-type interference on signals above 10 mc. The shunting effect of the limiter diode is appreciable only when the variable contact on R_1 approaches point B.

Modified Shunt-Type Noise Limiter

The limiter circuit in Fig. 12 resembles the series-type limiter of Fig. 1 except that the plate of the limiter diode and the low end of its cathode resistor are interchanged. As a result, the limiter diode acts to shunt C, thereby reducing the a-f output voltage whenever a noise-peak makes the diode conductive. The arrangement shown permits grounding the low end of the i-f transformer secondary when desirable for stability reasons.

Assume a constant carrier making point E on the detector diode load 10 volts negative with respect to A (ground). Points B and C are then both -5 volts to ground because the limiter diode is nonconducting, its plate being effectively at the -10 volt potential of E. The plate circuit time-constant is much longer than that of the cathode circuit of the limiter, so that any noise surge in excess of 20 volts across the entire detector load drives the cathode of the limiter diode more than 10 volts negative with respect to ground and the diode conducts, shunting the input to the following a-f stage. This shunting action is made more effective by series cathode resistor R_4, which with the limiter diode closed acts as part of a voltage divider to attenuate detector-load voltage peaks. Limiting action ceases when C becomes positive with respect to D due either to decay of the noise pulse or to charging up of C_2. The limiter will begin to cause audio distortion at about 100-percent modulation for the values shown. If R_2 equals 0.4 R_1, distortion will begin at about 40 percent modulation and a greater percentage of the a-f output developed across the detector load will be available to the following a-f amplifier. This limiter has been found to be much more effective than the simple shunt limiter, although not as good as the simple series-type limiter at the lower carrier frequencies.

Degenerative Noise Limiter

Degenerative feed to the i-f amplifier prior to final detection is used in the circuit of Fig. 13. A portion of the output from the first i-f amplifier is amplified in the first and second noise limiter amplifiers, and the resulting i-f output is coupled into a full-wave rectifier having R_1 as a load. The d-c voltage developed across R_1 provides the bias for the injector grid of a 6L7 pentode serving as the final i-f amplifier tube. Front-panel control R_3 provides a positive delay voltage for the diode cathodes, to prevent rectification until signal or noise peaks exceed this bias. Since the time-constant of the diode load is only 5 microseconds, the d-c potential across R_1 can fluctuate at a rate of up to about 200 kc.

If the normal carrier peak impressed across the diodes is 10 volts and the delay bias is 5 volts, the diodes do not rectify (since each gets only half the applied voltage) and the 6L7 injector grid then has substantially no bias relative to ground. Now if a 100-volt noise peak appears across the secondary of the diode transformer, the delay bias on each diode is exceeded by 45 volts and a negative potential of about 45 volts is therefore applied to the 6L7 injector grid. If this change in injector grid potential occurs simultaneously and in opposition to the change in the control grid potential of the 6L7 due to the same noise pulse and at the same rate, the effects of the noise pulse on the second detector can be reduced considerably by the resulting bucking action. Ideal phase and amplitude balance usually are, however, difficult to achieve, due in large part to the many circuits involved in the noise limiter amplifier and rectifier channel.

This limiter requires manual adjustment of the threshold of operation and is useless on fading signals. Circuits may be added to provide automatic biasing from an additional avc system, resulting, however, in almost prohibitive complexity. One version of this latter form has been found to be almost as effective as the simple series limiter at the higher signal frequencies. Modulation distortion is determined by the delay bias obtained from R_3 or by the accessory avc bias in the automatic form.

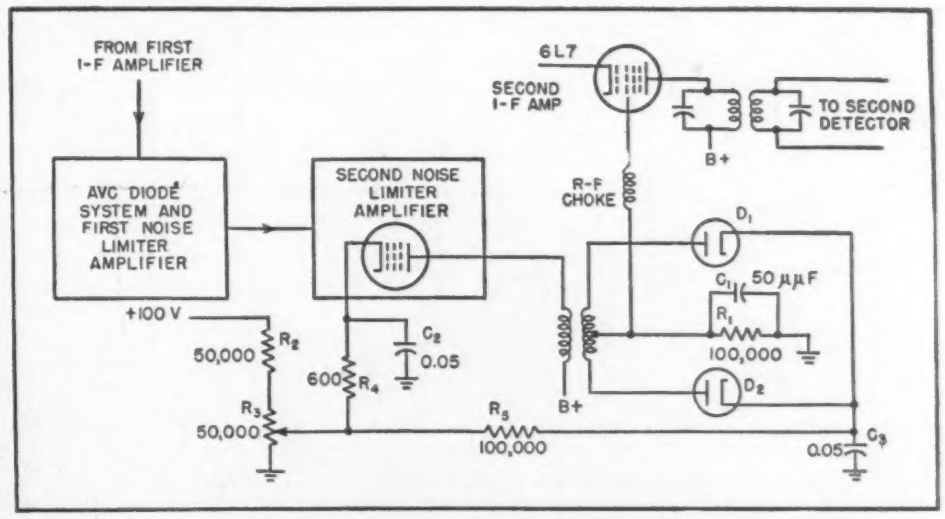


FIG. 13—Degenerative noise limiter, acting between first and second i-f stages

TEST OSCILLOSCOPE for Television

A modified standard oscilloscope is used to measure television transmitter modulation. Either the radio frequency or a video signal can be used for synchronization. Design and installation of additional circuit elements is discussed

THERE has been a definite need for some simple means of checking the modulation of television transmitters quickly and with reasonable accuracy. No commercial equipment suitable for operation at the high carrier frequencies involved has thus far become available.

It is possible to modify a commercial oscilloscope so that the technique of employing a trapezoidal pattern to measure modulation, used in sound broadcasting, may be adapted to television. The equipment provides a convenient means of determining the percent of carrier amplitude devoted to synchronizing pulses and hence compliance with the standard.

The modification necessary consists of providing a linear horizontal sweep at half the line or frame scanning frequency and of adapting the input circuits to the television carrier frequencies. The modified circuit of such an instrument is shown in Fig. 1.

Choice of Standard Oscilloscope

Use of the type 5JP1 cathode-ray tube is advantageous since the deflection plate leads terminate on the

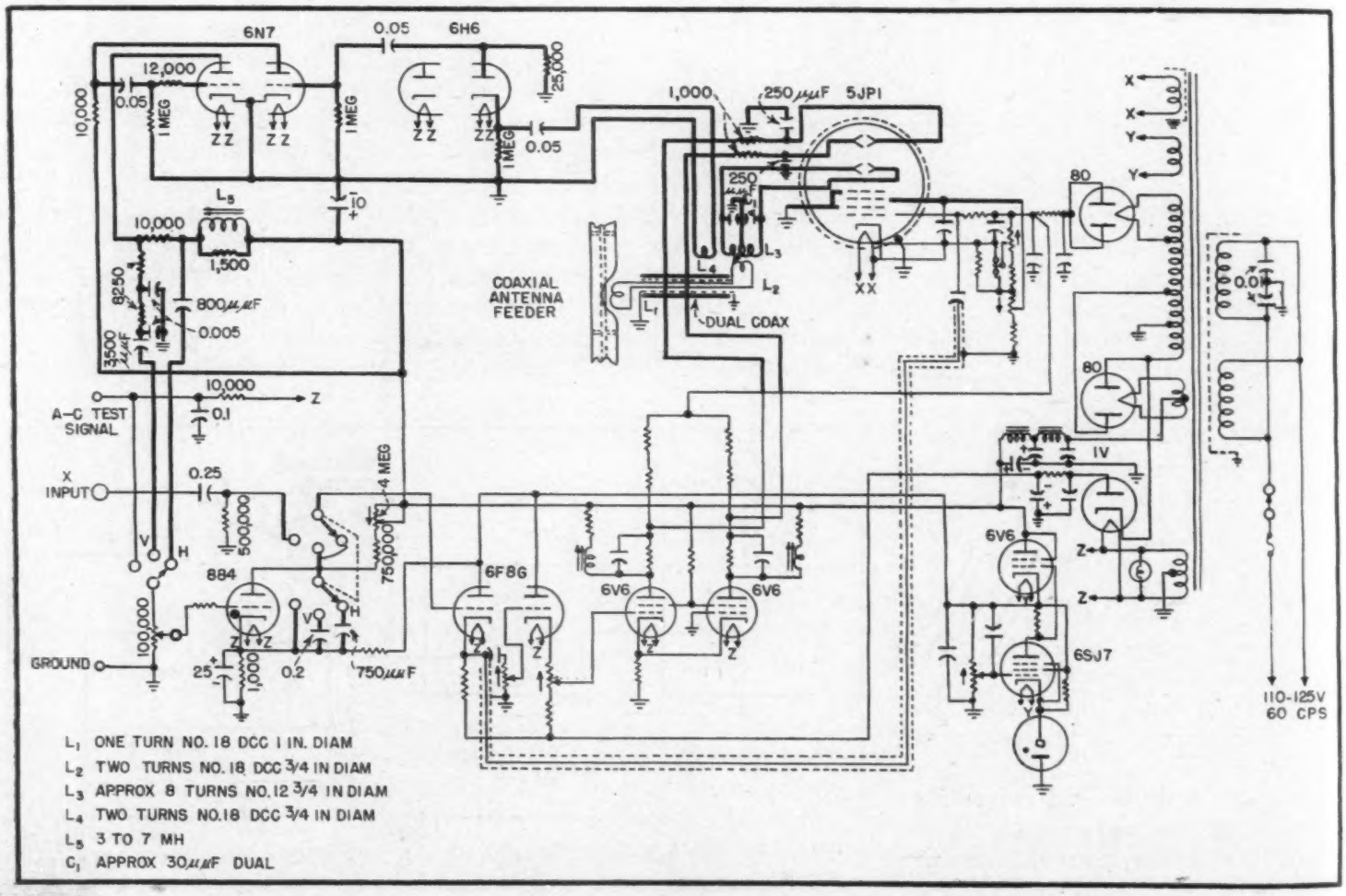


FIG. 1—Circuit modifications, shown in heavy lines, adapt standard oscilloscope for operation at television carrier frequencies

Stations

By A. H. BROLLY
and
W. R. BROCK

Engineers, Station WBKB
Chicago, Ill.

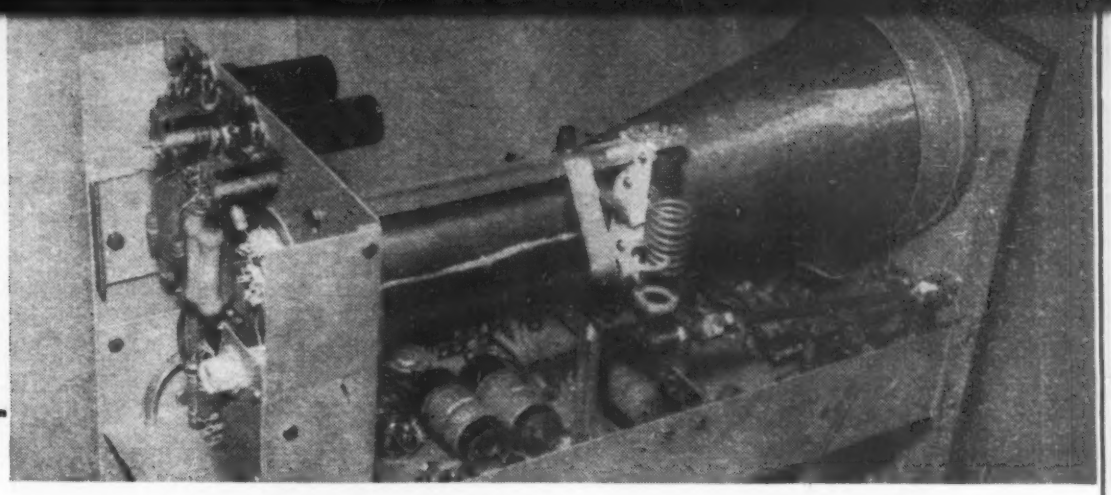


FIG. 2—High-frequency line terminating loop can be seen coupled to tuning coil of vertical deflection circuit in the converted oscilloscope

bulb. This feature minimizes capacitance coupling between horizontal and vertical plates, and simplifies the r-f circuit. It is desirable to shield the tube electrostatically by wrapping it in a sheet of copper foil as shown in Fig. 2, and to provide an aluminum or brass case for the whole instrument. In addition to shielding it is wise to isolate the leads from the horizontal sweep amplifier by some resistance to prevent any possibility of resonance in these lines. For this purpose 1,000 ohms was found satisfactory.

Filament, anode and bias supply circuits are those commonly employed in most oscilloscopes, with the exception that the high voltage supply should have a positive ground. This feature is important since it permits grounding the center tap of the tuned circuit and the use of low voltage r-f bypass capacitors on the horizontal deflection plates. The plate supply of the critical stages of the sweep amplifier is regulated and the horizontal sweep oscillator and amplifier are similar to those of conventional oscilloscopes with the exception of the synchronizing circuit and sweep-speed control.

The most critical consideration when using very high frequencies for vertical deflection is the tendency of these voltages to stray over to the horizontal deflection plates, causing a curvature of the parts of the pattern that should be vertical. The resulting image distortion can be prevented by symmetrical voltage distribution in the r-f circuit and effective r-f bypassing of the horizontal deflection plate leads. Capacitors must be selected that will have a low reactance at carrier frequency but a high reactance through the tenth harmonic of the horizontal sweep frequency. A 250 micromicrofarad capacitor has a reactance of 10.7 ohms at 60 megacycles and 8,100 ohms at 7,875 × 10 cycles and gives good results. The frequency 7,875 is one half the 15,750 cycles required for horizontal scan in 525-line television. This sweep frequency permits patterns of two scan lines to be shown on the screen.

The vertical deflection plates are driven by a tuned circuit that provides enough voltage at resonance to produce adequate deflection with small power input. In the lower group of television channels, 44 to 88 megacycles, a split-stator capacitor of 20 to 30 micromicrofarads per section is used for tuning. It is not necessary to load the circuits to pass the wide sideband since the highest frequency components in the extremes of the sideband are not necessary for ordinary measurements.

The center of the coil feeding the vertical deflection plates must be grounded to provide the required d-c potential on these plates. The rotor of the tuning capacitor may also be grounded. This common ground must be connected to the shield on the cathode-ray tube by a strap, ribbon, or wire of large area and as short as is feasible. Such an arrangement assures symmetry of voltage on the vertical deflection plates and reduces coupling to the horizontal plates.

A coil suitable for the lower group of television frequencies can be wound with no. 12 wire on a ¾-inch form. An 8-turn coil of this diameter has been found suitable for the 60- to 66-megacycle channel. One or two turns more or less will be required for other channels of the group.

R-F Pickup

To secure a balanced feed, a dual coaxial line is desirable. The line should be flexible so that it can be run through conduits or wire ducts with ease and its losses are low enough so that almost any reasonable length can be used.

Coupling coils at the input and output of the feed line are connected to the inner conductors and not to the outer sheath. The feed line input coil is a ¾-inch, one-turn loop inserted part way into an opening in the outer conductor of the transmitting antenna coaxial line just outside the transmitter cabinet. Where the coaxial line enters the oscilloscope cabinet the outer sheath must be grounded to the metal cabinet. The cable terminates in a two-turn coil of ¾-inch diameter and is loosely coupled to the tuned circuit of the oscilloscope.

Since such a loop cannot be expected to provide an entirely nonreflecting termination there will be some standing waves in the line, and some degree of unbalance in spite of precautions. Coupling between loop and tuning coil is ad-

justed by trial, inserting the loop a small distance between the turns of the coil; the most effective point may be found one or two turns above or below center as shown in Fig. 2. Because of standing waves in the line it is possible for the loop initially to be at a low-current point in the standing-wave pattern, in which case the line can be shortened somewhat.

Synchronizing voltage for the horizontal sweep may be taken from a video line if available or, if more convenient, it may be taken from the r-f signal (Fig. 1). The detector circuit shown is suitable for either method.

A small pickup coil of two turns is loosely coupled to the lower end of the tuned circuit and applies about a volt to the cathode of the 6H6 tube. This tube is located directly below the pickup coil so that the leads are kept short. Peaks of the r-f signal corresponding to the sychronizing pulses are rectified, biasing the cathode of the diode positively so that only synchronizing pulses appear in the plate circuit.

The diode performs the two functions of rectifying r-f and clipping off picture components. Negative impulses appear across the plate load resistor. If video signals are used for synchronizing, they may be applied to the diode that will serve in the same way to separate synchronizing pulses from the picture. If the pulses are negative with respect to ground, the signal is applied to the cathode of the 6H6 tube in the same manner as the r-f signal. If the pulses are positive, they are applied to the plate of the diode through a network consisting of a 0.05 microfarad capacitor and a one megohm resistor. The output is then taken from the cathode across a 25,000-ohm load resistor. In this case the output pulse is positive. This difference of polarity does not adversely affect synchronism of the sweep for reasons that will be pointed out later.

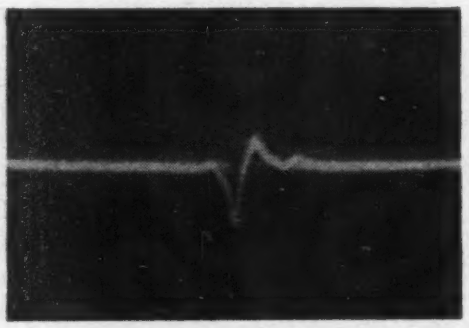


FIG. 3—Integrated vertical synchronizing pulse fed to the type 884 tube

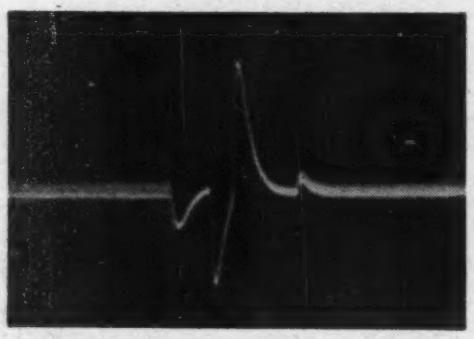


FIG. 4—Horizontal synchronizing pulse taken from L_3 through the *H* position of selector switch

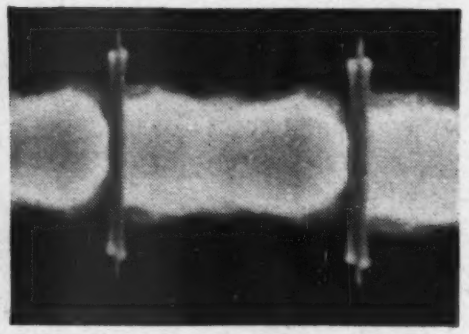


FIG. 5—One frame of a typical television signal as seen on the screen of the modified test oscilloscope

Signal Amplifier

The output pulses from the detector are amplified by the two-stage amplifier utilizing a type 6N7 tube that operates without external bias since the plate current is sufficiently limited by the 10,000-ohm plate resistors. As long as there is a substantial signal applied to this amplifier, grid rectification provides bias for the tube. The time constants of the grid resistor and coupling-capacitor networks are large enough to permit amplification of the 60-cycle field scanning impulses.

Impulses passing through the amplifier will usually be of both line and field frequencies. It is the function of the two networks in the plate circuit of the left section of the 6N7 tube to separate the two frequencies so that either can be applied to the horizontal sweep oscillator of the scope. The network consisting of two 8,250 ohm resistors and 0.005 microfarad capacitors, separates by integration the vertical pulse from the composite of both pulses. After separation the pulse is partially differentiated by the 3,500 micromicrofarad coupling capacitor and the 884 tube grid resistor producing both a positive and negative pip as shown in Fig. 3. Therefore, the polarity of the pulse from the 6N7 amplifier is unimportant since the 884 tube will always receive a positive impulse on which it synchronizes best.

The horizontal pulses are separated from the vertical by differentiation in L_3. Again a positive and negative swing is produced, as shown in Fig. 4, to synchronize the 884 tube.

Switching circuits are provided to select synchronizing voltage from either the vertical or horizontal separator output or from the 60-cycle line.

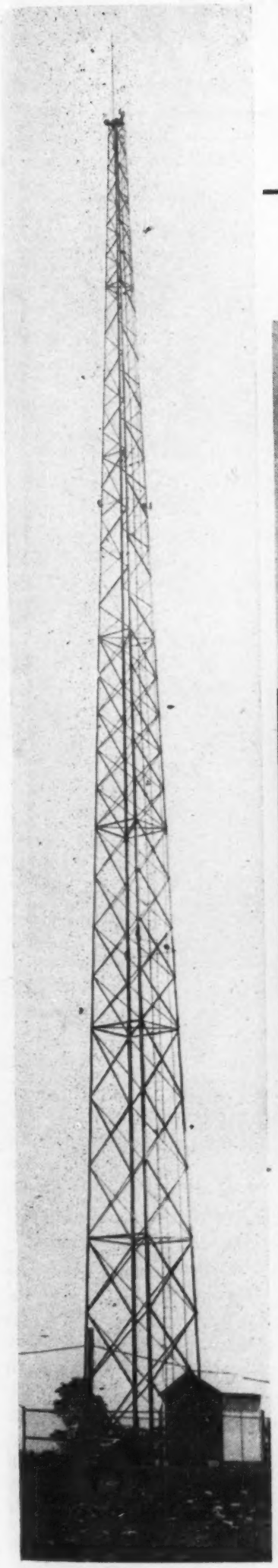
Appropriate *RC* networks can be switched into the plate circuit of the 884 tube to generate suitable sawtooth waves at 30 and 7,875 cycles for sweep speeds to show either frame or line patterns. Provision is made for external deflection for special cases. A potentiometer in the plate circuit of the 884 tube permits continuous adjustment of sweep frequency over a range from 3 or 4 lines or frames to one line or frame. The sawtooth output of the sweep oscillator is amplified by a 6F8G and two 6V6 tubes in a conventional circuit before being applied to the horizontal deflecting plates. A back-trace blanking impulse is fed to the cathode ray tube from the cathode circuit of the 6F8 tube.

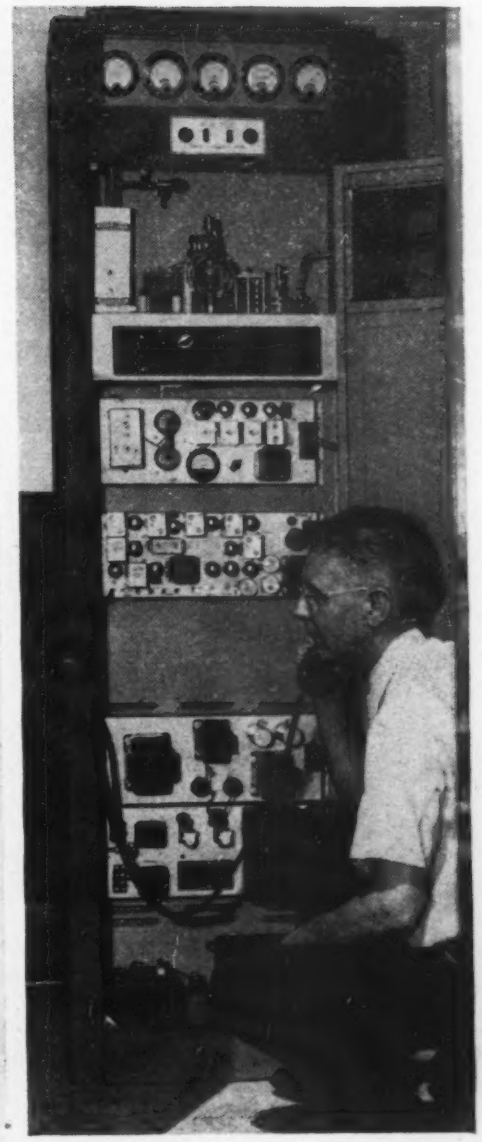
Use of the Instrument

A typical pattern of two frame periods of a television signal as it appears on the oscilloscope screen is shown in Fig. 5. The synchronizing pulse envelope may be seen at the vertical extremities of the pattern. Between these the horizontal line indicates the peaks of the line impulses.

At the base of the synchronizing impulses, the bright line indicates the blanking pulse shoulders or black level. The whole central portion of the pattern is taken up with picture components.

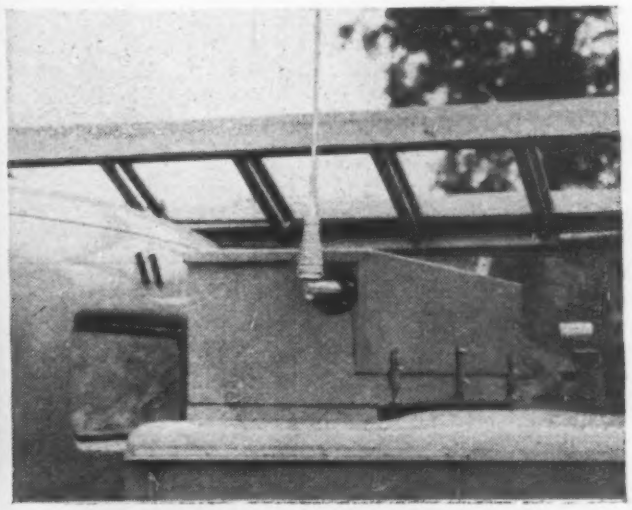
TWO-WAY RADIO for Power Line Crews





A TWO-WAY radio system employing frequency modulation on 37.18 megacycles has proved the answer to West Penn Power Company's problem of providing quick and reliable communication between central stations and service trucks when line trouble develops. Fourteen trucks have been equipped, each having a 35-watt transmitter, and the 250-watt fixed station with call letters WNAA is now in regular operation at the company's principal substation. Reliable reception is obtained in trucks within a 30-mile radius of Charleroi in all kinds of weather, and the station has been heard up to 150 miles away. Mobile radio is now being planned for the rest of the system.

BELOW—The Link radio equipment for each truck is in a weatherproof cabinet just behind the cab, with whip antenna mounting at side



ABOVE—Transmitter of main station is located in small house at base of tower, and remotely controlled from four points in Charleroi, Pa.

LEFT—Transmitting antenna atop 175-foot steel tower

LOWER RIGHT—Radio hand-set and control panel are conveniently located in cab of each truck. Controls are, left to right: squelch switch, transmitter pilot lamp, receiver pilot lamp, and volume control. Receiver is in operation at all times for emergency calls, and push-to-talk switch on hand-set is the only transmitter control

Components of

By EDUARD KARPLUS

Engineer
General Radio Co.
Cambridge, Mass.

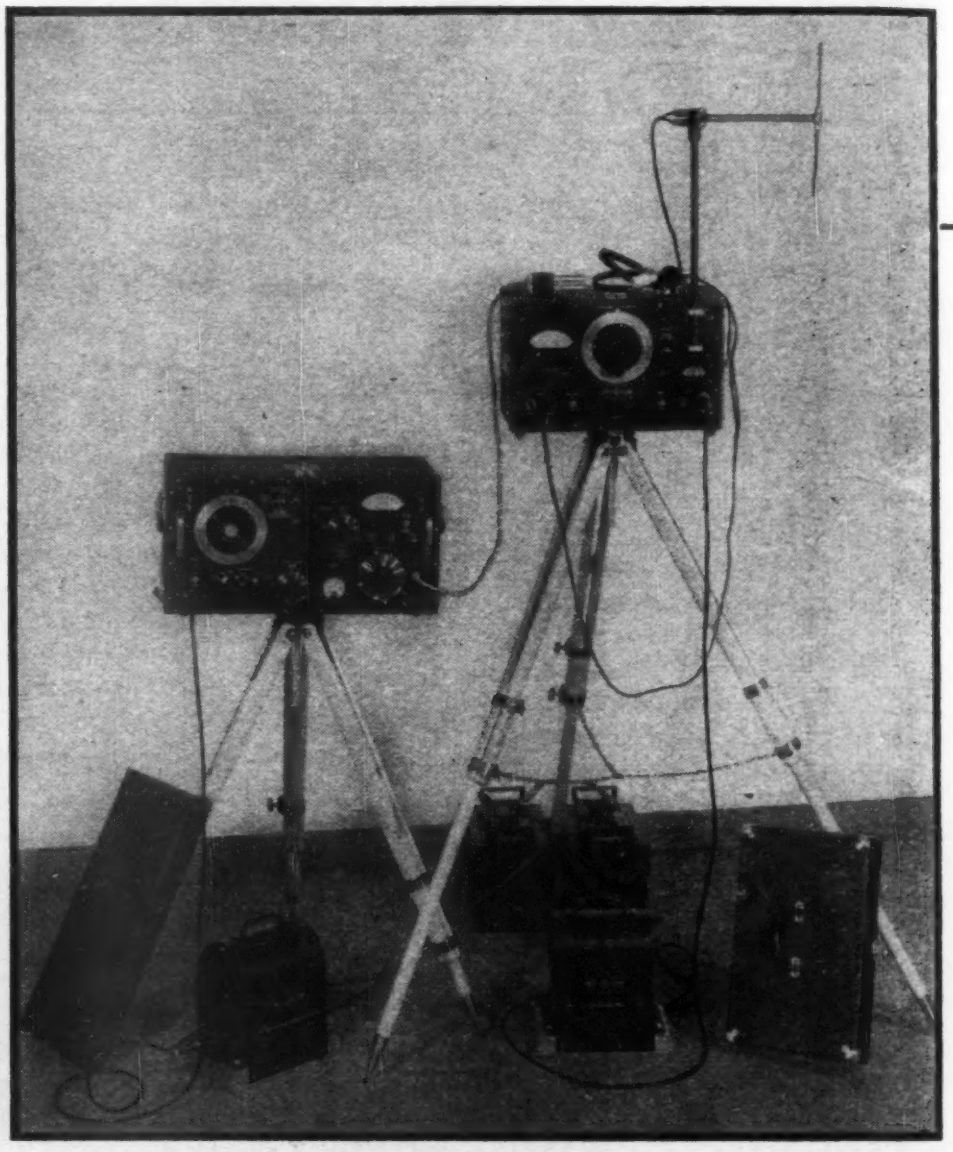


FIG. 1—Field-strength meter and standard-signal generator developed for National Defense Research Committee by General Radio Co. to be used for measurements between 300 and 1,000 mc

FREQUENCY LIMITS of electronic equipment were rapidly pushed into the hundreds of megacycles during war development. To learn about propagation and equipment capabilities a field strength meter was developed for the range from 300 to 1,000 mc. This meter was intended for measurements in the laboratory or field. It had to be quickly tunable to any frequency within its range. A sensitive receiver, which could be calibrated by a standard signal generator, was required to measure the voltage induced by an unknown field in an antenna of known characteristics. The completed equipment for making these measurements is shown in Fig. 1.

Field Strength Measurements

In using the field strength measuring equipment the antenna and receiver are tuned to the incoming signal; the antenna is disconnected from the receiver and replaced by a dummy antenna and a standard signal generator which is adjusted to give the same receiver response. The field strength ϵ in microvolts per meter is related to the standard signal generator voltage E in microvolts by

$$\epsilon = E\frac{1}{h_e}$$

where h_e is the height of the antenna in meters. If the antenna is adjusted to half-wave resonance

$$h_e = 0.636l = 0.636\frac{\lambda}{2} = \frac{95}{f}$$

to a first approximation, where f is the operating frequency in megacycles. Therefore the unknown field strength is

$$\epsilon = 0.0105 f E$$

The receiver and the standard signal generator have since found wide application in other fields, and, although the original models are obsolete today, many of their components will be found useful in similar applications.

Tuned Circuits

The butterfly circuit, as well as its application in negative-grid triode oscillators, has been described in detail,[1] but the wide interest shown in this development justifies a few further remarks.

The butterly circuit used in the signal generator has 2½-inch outside diameter and 5 and 6 plates on the rotor and stator respectively, has a tuning range of 220 to 1,100 mc and is equipped with terminals for grid and plate of the oscillator tube. The butterfly circuit can be considered a parallel combination of inductances and capacitances. This combination is seen in the schematic diagram of Fig. 2 where the capacitive branch is represented by two series capacitors and the inductive branch by two parallel inductors between terminals one and two. Variation of both capacitance and inductance is brought about by rotation of the inner, butterfly shaped, member. The capacitive branch is the familiar series-gap tuning capacitor. Variation of the two identical inductive branches is achieved as the rotor progressively blocks out the area through which a magnetic field can pass.

At 220 mc, with the plates fully

UHF Field Meters

Tuning limitations of resonant circuits, tunable doublet antenna, uhf voltmeters, cavity attenuators, power-supply stabilizer of early model of field-strength meter, and standard-signal generator are described

meshed, the effective inductance of the circuit is 0.011 μh, the effective capacitance is 48 $\mu\mu$f, and the effective Q is 650. The corresponding values at 1,100 mc are 0.004 μh, 5 $\mu\mu$f, and a Q of 300.

Common to all butterfly circuits is a series-gap capacitor for capacitance variation across two fixed terminals, which eliminates the necessity of sliding contacts, and the direct incorporation of a parallel inductive path into the structure of this capacitor. This integral design is important in reducing metallic losses at points where capacitive and the inductive paths of the tuned circuit join and makes it possible to use lumped parameter elements at these high frequencies. The eddy-current shielding effect of the rotor plates, which reduces the effective inductance in the high frequency position, helps to obtain very wide tuning ranges, but increases the losses to some extent.

If low losses are important, and wide tuning ranges are not required, butterfly circuits should not be used. Better results can be obtained with a cylinder circuit.[2] This circuit can be represented by a diagram similar to Fig. 2 with a single and fixed inductive branch. The tuning ranges of cylinder circuits are considerably smaller than the ranges obtained with butterfly circuits, but their losses are lower and their Q's are practically constant. A cylinder circuit with cylinders one inch in diameter and two inches in length has a tuning range of approximately 500 to 1,000 mc with a Q of 1,200.

In a broadcast receiver a three-to-one frequency variation is ordinarily produced by a 180 degree rotation of the capacitor shaft, but a typical butterfly circuit varies from 220 to 1,100 mc between two rotor positions which are only 90 degrees apart. To compensate for this difference, and for an uneven frequency distribution, the angular precision of the drive has to be about seven times better in the butterfly circuit than in a comparable variable capacitor circuit. The precision required to prevent axial movement of the plates is the same in both cases provided the air gap and the care used in centering the plates are equal. This relation is based on percentage accuracy and has to be multiplied by the ratio of frequencies if frequency increments are considered. In our example this ratio would be 1,000.

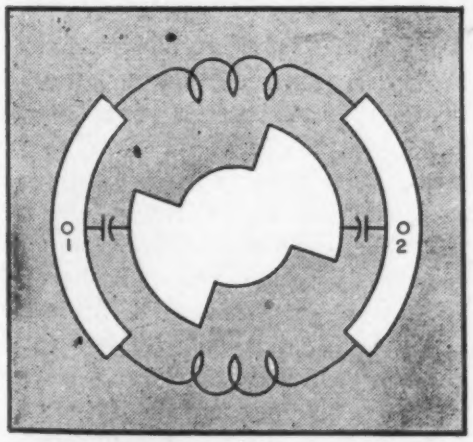
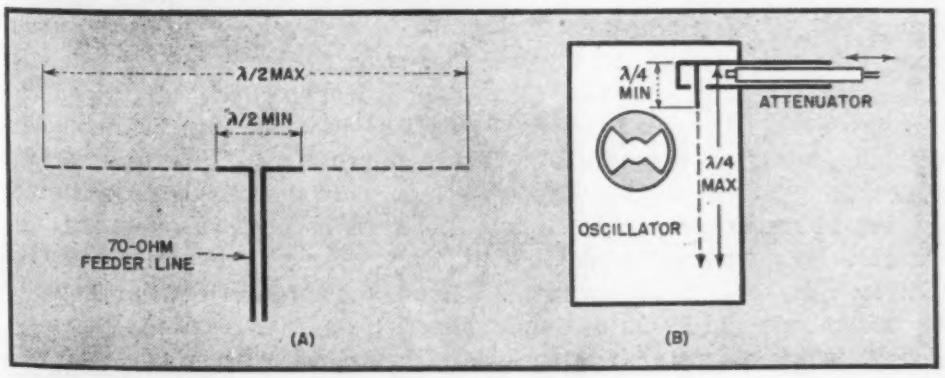


FIG. 2—Left—Schematic diagram of butterfly circuit indicates that high resonant impedance appears across points 1 and 2

FIG. 3—Below—(A) Tunable antenna and (B) attenuator coupling are principal uhf features of equipment



Frequency Limits

The 220 to 1,100 mc butterfly circuit has an air gap of 0.04 centimeter, which is not adequate for high-power applications. If this air gap were changed to 0.2 centimeter, the maximum capacitance across the terminals would be reduced to one fifth its previous value and the frequency range would be 500 to 1,000 mc, to a first approximation. This large reduction in tuning range cannot be offset by an over-all increase in the size of the unit. A 50 percent increase in diameter would increase both capacitance and inductance by a factor of about 2.3 and would approximately restore the bottom frequency of 220 mc, but the top frequency would have dropped to under 700 mc. An increase in the number of plates would seem to be a possible solution, but unfortunately butterfly circuits with more than a certain number of plates have spurious modes which interfere with their proper operation. It appears, therefore, that the maximum size and the maximum number of plates that can be used in a butterfly circuit are limited by the top frequency, and that the bottom frequency is then determined by the air gap.

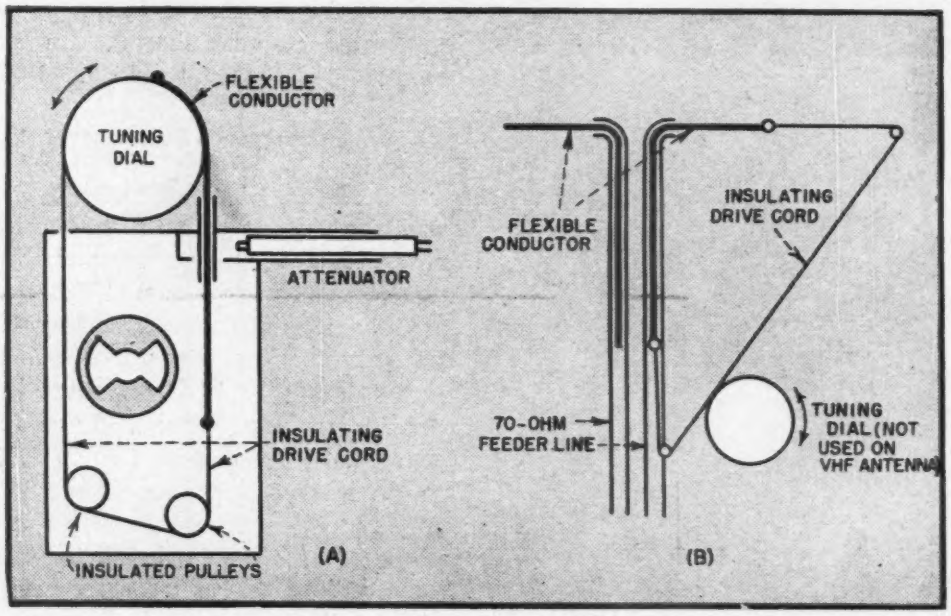
In practice it is very hard to compute the top frequency of a butterfly circuit without a good deal of experi-

mental data taken from similar designs because the mechanical shapes determining both capacitance and inductance are too complicated for simple approximations. The bottom frequency can be obtained with reasonable accuracy if the capacitance of the series gap capacitor is computed as in any low-frequency application and the inductance as

$$L = 4.9\, r \log_{10} (r/t + w)\ 10^{-9}\ \text{Henry's}$$

where r is the inside radius of the butterfly stator plates and t and w are thickness and width of the stator stack, all in centimeters. To arrive at an estimate of the top frequency of a butterfly circuit, a range factor is used which varies between two and 12 for the circuits that have been built so far. The range factor increases as frequency and air gap are reduced.

FIG. 4—Experimental drive systems for flexible conductors used (A) to couple from oscillator into attenuator cavity and (B) to tune doublet antenna



Tunable Resonator

Another component of general usefulness is a tunable resonator which is incorporated in the signal generator and in the receiver of the field strength measuring equipment. In both cases resonators with a five-to-one frequency range were required and adjustment by turning a dial seemed desirable. Figure 3 shows schematically these two applications.

In Fig. 3A a 70-ohm feeder line is connected to a doublet antenna, the length of which has to be $\lambda/2$ at the operating frequency. In Fig. 3B a mutual inductance type attenuator is coupled to a 220 to 1,100 mc butterfly oscillator. A quarter-wave resonator with the current loop in the attenuator produces a strong field of the desired mode and reduces in proportion undesirable modes which might otherwise cause errors in attenuation.

This same system was used in a 1,000 to 3,000 mc signal generator to select, in addition, the second and the third harmonics of a 500 to 1,000 mc oscillator. In this particular case the oscillator used a quarter-wave open line and could be driven much harder for harmonic generation than would be possible with a butterfly oscillator.

In both cases conventional telescoping tubes could have been used, but for a five-to-one frequency range at least five joints would have been required. The solution adopted consists, instead, of a short fixed guide and a long flexible conductor which is pushed through the guide by the amount required to produce resonance. In the attenuator, which is illustrated in Fig. 4A, the remaining part of the conductor, which is not required at a particular frequency setting, does not constitute a problem because it passes through the oscillator shield into the outer space and cannot interfere with the components inside the shield. Good contact between conductor and guide is important. As shown, the flexible conductor can be tied to an insulating drive cord and be guided and driven by pulleys operated by a conveniently located dial. By proper choice of the location and size of the insulated pulleys inside the oscillator housing, coupling between the resonator and the oscillator can be adjusted over the frequency range.

Conditions in the tunable antenna are somewhat different because no ground plane is available for separating the used and the unused parts of the resonator. In that case, the flexible resonator is fed through a hollow feeder line as shown schematically in Fig. 4B. The feeder line is composed of two tubes spaced to provide the desired characteristic impedance of 70 ohms and bent at the upper end to give the flexible resonator a right angle deflection. The unused parts of the resonators are within the feeder lines and do not disturb the field of the antenna.

To avoid complications, a driving mechanism has been omitted in the 220 to 1,100 mc doublet antenna shown in Fig. 5. The feeder lines are aluminum channels spaced for 70-ohm characteristic impedance by a polystyrene bar. The flexible conductors are self-supporting flat strips of slightly curved spring material, similar to the strips used in the familiar steel rules. Adjustment of antenna length is easily made by hand using pins which are fastened to the conductors and project through the aluminum channels.

Crystal Detectors

After a careful study of uhf voltmeters, it was decided to use a crystal detector as the rectifying element because, in spite of all their shortcomings, voltmeters of this type can be built with lower corrections for frequency than any of the others. A suitable crystal detector had to be developed for this application in 1941, but today completely sealed detector cartridges with standardized dimensions and reliable performance are available.

Up to a few thousand megacycles the action of the detector junction is independent of frequency if precautions are taken in its manufacture and the frequency characteristic of a crystal detector type voltmeter is determined by its resonant frequency. Series resonance of the shunt capacitance of the detector junction and the lead inductance between voltmeter terminals increases

the voltage E appearing across the detector junction with respect to the terminal voltage e and causes a corresponding frequency error F such that

$$F = \frac{E}{e} = \frac{1}{1 - (f/f_0)^2}$$

where f and f_0 are operating frequency and resonance frequency of the voltmeter respectively. In any particular voltmeter design the resonant frequency f_0 varies only slightly with individual detector cartridges. In a typical application, using the type 1N21-B detector, which is the most suitable for this purpose, the resonant frequency varies from 3,500 to 3,900 mc, corresponding to a frequency error of 9 to 7 percent at 1,000 mc.

Erratic variation or drift of crystal detectors have been largely reduced by modern design and it has been found that in most cases the drift is independent of frequency. Because this assumption is certainly correct for small drift, detectors can be checked periodically and corrected at any convenient frequency, for instance at 60 cps.

Another peculiarity of crystal detectors which sets them apart from vacuum-tube voltmeters and thermocouples, ordinarily used at lower frequencies, has to be mentioned as it bears on their application. Vacuum-tube voltmeters can be built for a wide range of voltages, and their circuits can be so designed that no permanent damage is done by overloads. Thermocouples can be built for a wide range of currents. They are readily burned out, but this damage is immediately obvious. Most crystal detectors will not stand more than a few volts, and great care has to be taken to prevent overloads which might change the characteristic of their junction before it is made ineffective or burned out.

Attenuator

A voltmeter placed at the input to the attenuator of a signal generator will read independently of attenuator setting, but a voltmeter placed at the output terminal will read only over a limited range of low attenuation. It would seem, therefore, that the first location, which is always used at low frequencies is more desirable, but at ultrahigh frequencies the second method will give more accurate results.

In both cases the accuracy at low output voltages depends on the attenuator calibration, which can be computed precisely for the mutual inductance type attenuator commonly used at ultrahigh frequencies. The quarter-wave resonator described in connection with Fig. 3B is not required, and better results are obtained if the end of the attenuator tube is fitted with a shield to exclude undesirable modes and is pointed toward a part of the oscillator circuit which carries current in the plane of the pickup loop. The field of this current passes the shield and enters the attenuator tube where it is attenuated logarithmically, decreasing by 32 db for each diameter traveled.

If a voltmeter is placed at the output side of a line connected to the pickup loop, a reference point of attenuator output voltage can be established for any position of the pickup loop that provides sufficient voltage to make the meter read, and accurate lower output voltages can be obtained by moving the pickup loop by accurately determined amounts. A complete output system

FIG. 5—Doublet antenna can be quickly tuned by sliding flexible tapes in two-wire transmission-line track

of this type includes resistors, R_1 and R_2 and capacitor C, as shown schematically in Fig. 6. Resistor R_1 is required to terminate approximately the short line between pickup loop and voltmeter in order to prevent excessive voltage rise which might overload the crystal detector, if the proper load is not connected. Resistor R_2 is a matching resistor to provide desirable values of output impedance. It will ordinarily be determined by the characteristic impedances of the cable connecting the load and was 70 ohms in the field strength measuring equipment to simulate the radiation resistance of the doublet antenna. Capacitor C is sufficiently large to be

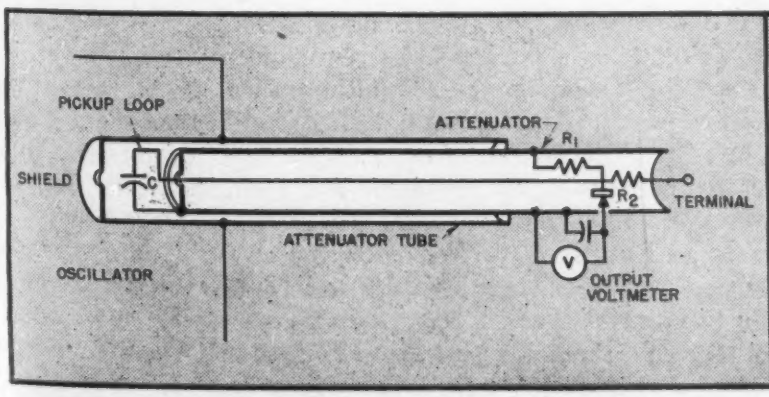


FIG. 6—Output meter of standard-signal generator can be located at output of attenuator

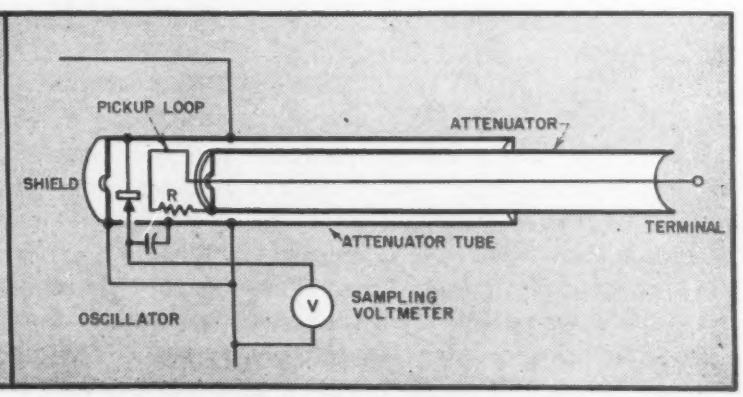


FIG. 7—Output meter of standard-signal generator can be located at input to attenuator

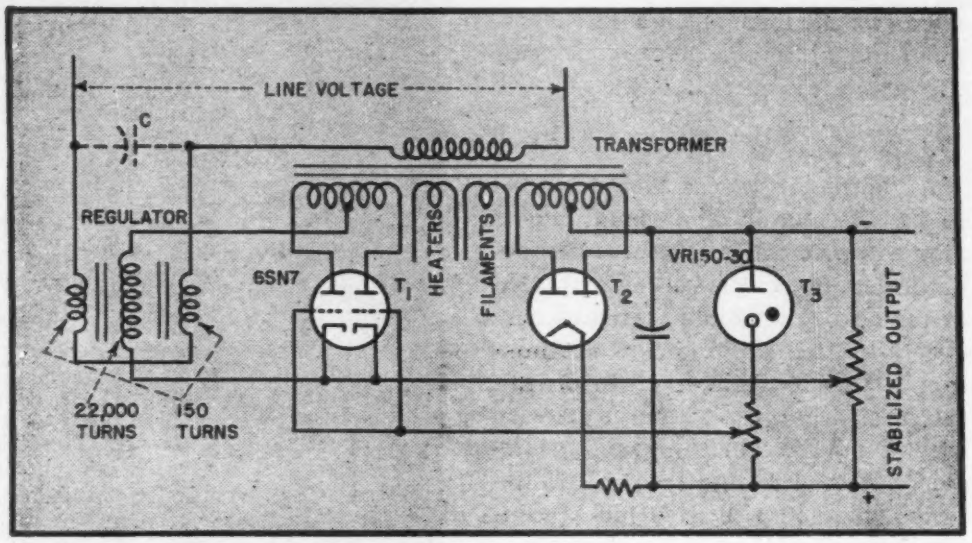


FIG. 8—Power-supply stabilizer, to regulate both filament and heater as well as high-voltage supply, uses controlled saturable reactor in power input circuit

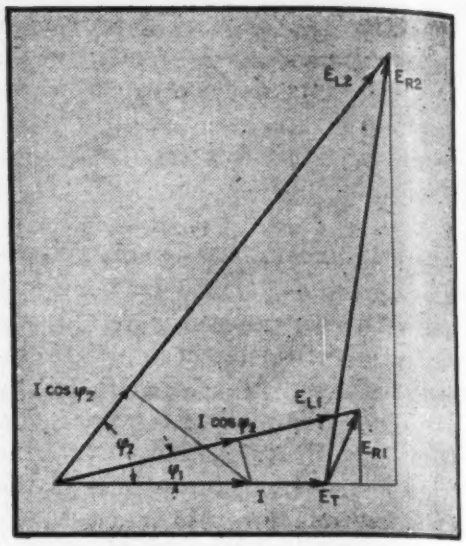


FIG. 9—Vector diagram shows that reactor absorbs the change in input voltage

ineffective at radio frequencies and has been inserted only to facilitate low frequency calibration of the crystal detector.

In this output system, the accuracy of output voltage at the reference point is determined by the voltmeter alone and does not depend on any other circuit elements. The accuracy of the output impedance is determined by R_2 alone because this resistor is immediately preceded by the output voltmeter, which can be considered a zero-impedance source. Obviously no signal generator could have sufficient power to meet this requirement, but as long as its output voltmeter is reset to the same value whenever the load is changed, the terminals of the voltmeter have all the characteristics of a zero-impedance source. In operation, therefore, the reference level of the logarithmically calibrated attenuator has to be established with the load connected, and as we have seen, this has to be done at a high output level to provide a reliable reading of the output meter. If, for some reason, the load changes with the signal amplitude, the attenuator calibration will be in error.

Alternative Output Circuit

To follow the more conventional output system the voltmeter is placed at the attenuator input as shown in Fig. 7 where it samples the field in the attenuator tube. This field decreases within the attenuator according to the same logarithmic law as before. Output voltage depends on the size and position of the pickup loop, the output impedance on the characteristic impedance, and length of the short line connecting the pickup loop with the output terminals. To eliminate a frequency dependent effect, this line has to be terminated at the pickup loop. Resistor R is inserted for this purpose, but because the reactance of the pickup loop itself is included in the termination, an accurate solution of this problem is difficult at uhf.

If an adequate solution is possible at lower frequencies, however, or over a limited range at some high frequency, two advantages are obtained, compared to the output system shown in Fig. 6. That the output meter reads at all attenuator settings is convenient as mentioned before. In addition the generator voltage is now independent of the load because it is determined by field strength in the attenuator tube.

Both these disadvantages of the simpler and more accurate system, which uses the meter at the output terminal, can be overcome. The crystal-detector type output meter has to work at a low level to prevent damage to the crystal junction and will not be able to indicate modulation peaks. By coupling a high-level peak-reading diode voltmeter to the oscillator, modulation can be determined accurately. In addition, a permanent indication of oscillator amplitude is obtained which is useful for monitoring purposes even if it cannot be made proportional to the output voltage. To eliminate errors caused by a load that changes its impedance at high levels, an attenuation pad can be inserted between the terminal of the signal generator and the load, or resistance R_1 and R_2 of Fig. 6 can be rearranged to give a fixed initial attenuation.

No matter which attenuator output system has been used, terminals for connecting the load have to be provided. At uhf this connection is always a matched concentric cable, and no particular advantage is obtained by locating the signal generator output terminal at the end of another cable as is customary at lower radio frequencies. The output terminal, in form of a concentric cable fitting, can be located on the front panel of the instrument.

Regulated Power Supply

Another problem encountered in the design of the field strength measuring equipment concerns the power supply. The equipment was built for 60-cps operation, but for at least part of the time the power required had to be produced by a motor-generator set driven from a storage battery. Under these conditions both voltage and frequency vary widely. Some means had to be provided to regulate filament and plate supplies,

The regulated power supply adopted for the field strength measuring equipment presents a solution of this problem by magnetic and electronic means. The fundamental schematic diagram is shown in Fig. 8.

The two outer a-c windings of the regulator are connected in series with the power transformer. A d-c winding is energized from a twin triode tube T_1 which acts as a grid-controlled rectifier. The reactance of the regulator is determined by the d-c

current in the middle winding and automatically varies to maintain the primary voltage of the transformer constant.

Control voltage for the rectifier tube T_1 is derived from the main B-supply. At normal line voltage the grids of tube T_1 are slightly negative with respect to its cathode and allow some current to flow through the d-c winding of the regulator. At higher line voltages the grids become more negative because the voltage across the glow tube T_2 does not change. The rectified current through T_1 then decreases and the impedance of the regulator increases to bring the primary voltage of the transformer back to its previous value.

Regulator Design

Figure 9 shows voltage and current relations of the system for minimum and maximum line voltage E_{L1} and E_{L2}. Line current I and transformer voltage E_T are independent of line voltage. E_{R1} and E_{R2} are the voltages across the regulator which are out of phase with the line current except for a small component which covers the a-c losses in the regulator and increases slightly with line voltage. Input power, therefore, is essentially constant including a regulator loss of about ten percent. The phase angle of the input power varies between ϕ_1 and ϕ_2 and can be corrected for average line voltage by a fixed capacitor across the line terminals.

To compute the regulator characteristics, the power required by the instrument and the expected line voltage variations have to be known. By assuming a minimum voltage drop E_{R1} in the regulator, the operating voltage of the transformer E_T, the line current I, and the maximum volt-amperes IE_{R2} that the regulator has to handle can be established. For good regulation, the flux density in the regulator should be kept low. At high flux densities, considerable distortion of current waveform results, which causes poor regulation in the filament and heater supplies. It should be remembered that the regulation control voltage is derived from the main B-supply, which is proportional to the rms value of heater current only as long as the waveform of the power source remains constant. Depending on filter circuit and load, output voltage of the B-supply will be determined by average or peak values of the power source rather than by its rms value. The flux density of the regulator is determined by its ampere-turns IN_1 and the length of its magnetic path l_1 where N_1 is the total turns of the two outer a-c windings and l_1 is the outer circular path of the core. The maximum regulator voltage E_{R2} is determined by the cross-section of the core, the flux density, and the total turns of the a-c windings.

To reduce the regulator voltage to its minimum E_{R1}, the core material is saturated by d-c current in the middle winding. The ampere-turns required are now determined by the shorter path l_2 through the center leg and the two outer legs in parallel. Because the magnetizing current is furnished by a vacuum tube, the d-c resistance of the middle winding can be high and its number of turns N_2 can be many times larger than N_1. The two halves of the outer winding have to be well balanced because no a-c voltage should appear across the middle winding.

Magnetizing current is produced in the grid-controlled full-wave rectifier T_1. The plate voltage of this tube is derived from the main power transformer and should be high enough to allow the maximum current required for regulator saturation to flow without grid current. Control voltage for this tube is obtained from the glow tube and potentiometer combination across the B-supply of the instrument. Ordinarily the gain in the grid-controlled rectifier T_1 will be sufficient to change the magnetizing current of the regulator over its full range with a very slight variation of the B-supply output voltage, but there is no reason why additional gain could not be inserted between T_2 and T_1.

The characteristic curves of the power supply used in the signal generator are given in Fig. 10. The power requirement of the main instrument transformer is 70 watts, and it operates at 75 volts. It will be seen that the operating range of the regulator is extremely wide at 60 cps and is still adequate at 40 cps. Regulation of the heater supply is not as good as that of the B-supply, particularly at 40 cps. This inadequacy is due to distorted waveform of line current and has been partly corrected by capacitor C of 6 μf across the regulator.

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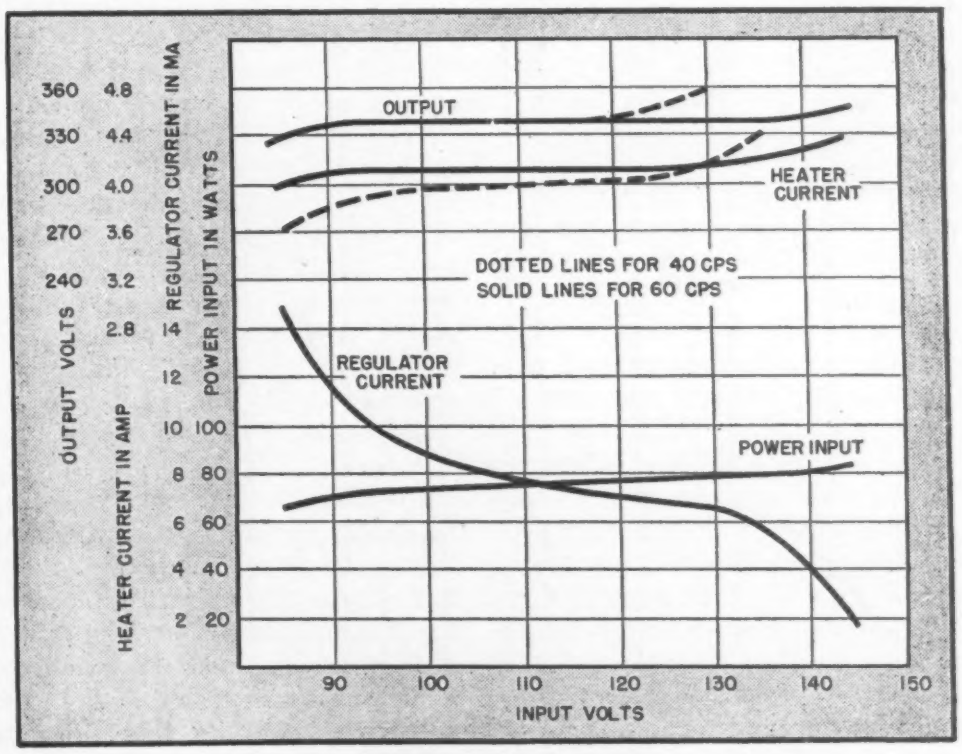

FIG. 10—Measured characteristics of power supply show the wide range over which the stabilizer operates

CONSTANT CURRENT

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Exponential circuits can be made to carry more nearly constant current for longer times if corrective networks are used. Design equations and actions of these circuits are derived, and their advantages in magnetron pulse circuits are illustrated by a numerical example

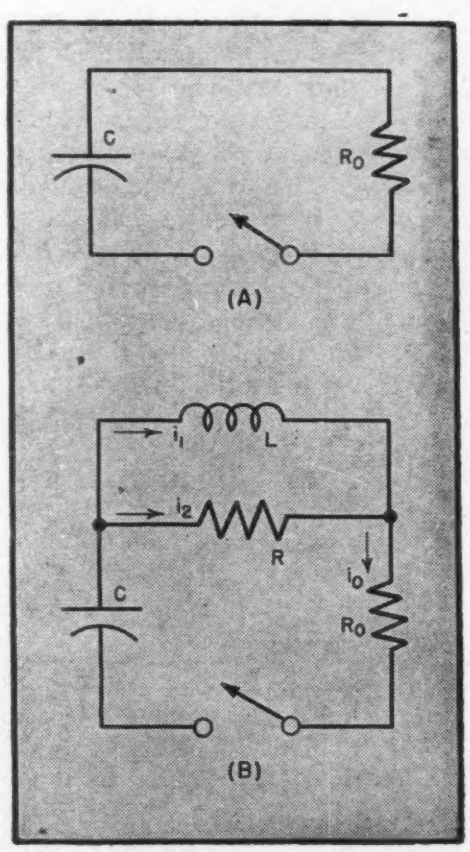

FIG. 1—(A) Exponential circuit, and (B) compensated circuit from which constant current can be obtained

EXPONENTIAL charging and discharging currents in resistance-capacitance or resistance-inductance circuits can be made approximately constant for short durations by inserting low-loss networks. Such networks permit reducing the capacitance by a factor of four or more for a given pulse duration, or increasing the pulse duration four times for a given capacitance and percent drop in current during the pulse. Similar results can be achieved in inductive circuits.

Reduced size of the reactive element made possible by these networks results in reduction of cost, bulk, and weight of the constant-current circuit. In applications where frequency stability of a self-excited magnetron oscillator is dependent upon tube current, the improved uniformity of current from these networks gives more stable operation.

The Problem

When a capacitor is charged or discharged through a resistor, the resultant current is an exponential function of time. However, in sawtooth sweep circuits, discriminating counter circuits, and other circuits involving pulses of constant amplitude, it is sometimes necessary or desirable to maintain constant current through a resistor, or resistive load for an arbitrarily short period of time. This requirement is especially necessary in one type of radar transmitter in which part of the energy stored in a capacitor is periodically discharged into a magnetron oscillator in the form of rectangular pulses. Approximately constant current can be obtained by inserting a parallel resistor-inductor network in series with the resistor-capacitor circuit.

To determine optimum values of these circuit parameters, consider the case of a capacitor C charged to potential E and then discharged through resistor R_o when the switch of Fig. 1A is closed. It is desired to have the current through R_o remain constant for a short interval ΔT. An inductor and resistor are inserted as in Fig. 1B. The relationship of the various parameters is determined by the following analysis.

By Kirchhoff's Laws

$$L\frac{di_1}{dt} = Ri_2 \qquad (1)$$

$$i_o = i_1 + i_2 \qquad (2)$$

$$\frac{q}{C} + L\frac{di_1}{dt} + i_oR_o = 0 \qquad (3)$$

Because it is assumed that i_o is constant, that being the desired condition, let i_o equal I_o, a constant. Then from Eq. 1 and 2

$$L\frac{di_1}{dt} = R(I_o - i_1)$$

or

$$\frac{di_1}{dt} + (R/L)i_1 = (R/L)I_o \qquad (4)$$

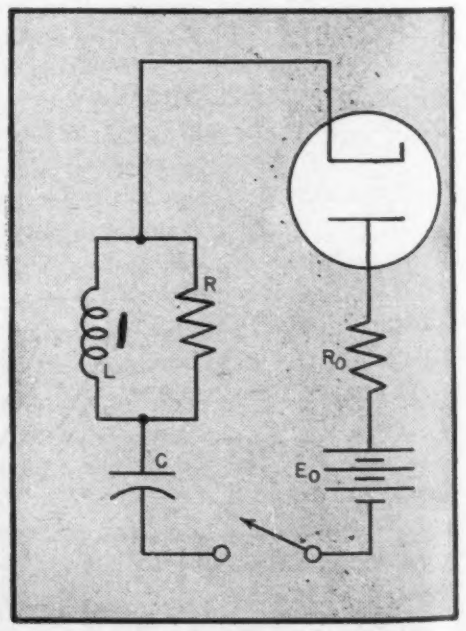

FIG. 2—A biased diode can be a part of the load through which constant current is passed

CIRCUITS

The complementary solution of Eq. 4 is $i_1 = A\epsilon^{-(R/L)t}$ where A is an arbitrary constant. The particular solution is $i_1 = I_0$. The complete solution is therefore

$$i_1 = A\epsilon^{-(R/L)t} + I_0 \qquad (5)$$

Conventionally, this equation indicates that I_0 is a steady-state condition, which is obviously impossible. However, because the time interval under consideration is very short, no steady-state condition is reached, and thus Eq. 5 is legitimate.

When $t = 0$, $i_1 = 0$. Therefore, in Eq. 5, $A = -I_0$, and

$$i_1 = I_0(1 - \epsilon^{-(R/L)t}) \qquad (6)$$

Differentiating Eq. 6 with respect to time and multiplying by L, we obtain

$$L\frac{di_1}{dt} = I_0R\epsilon^{-(R/L)t} \qquad (7)$$

Substituting this equivalent into Eq. 3 gives

$$\frac{q}{C} + I_0R\epsilon^{-(R/L)t} + I_0R_0 = 0 \qquad (8)$$

Differentiating Eq. 8 and substituting I_0 for dq/dt gives

$$\frac{I_0}{C} - \frac{I_0R^2}{L}\epsilon^{-(R/L)t} = 0 \qquad (9)$$

If L/R is much greater than ΔT, then $\epsilon^{-(R/L)t}$ is approximately unity during the pulse interval. Thus Eq. 9 reduces to the familiar relationship: $R = \sqrt{L/C}$ or $L = R^2C$.

Circuit Modification

It is evident in the foregoing analysis that the value of R_0 does not affect the result. Consequently, if R_0 is replaced by a biased diode as in Fig. 2, it would be expected that for constant current the same relationships of the parameters must hold. In this case capacitor C is given, charged to a potential E, which is to be discharged through a load with constant current for a time interval ΔT after the switch is closed. The load in this case is a diode in series with a battery. Resistance R_0 represents the sum of the diode resistance, the switch resistance, and any other resistance in the circuit. The R-L network is inserted as before and the analysis is similar.

A new term, E_0, will appear in Eq. 3 and 8. However, this term disappears when Eq. 8 is differentiated, resulting in the same Eq. 9 and consequently the same two relationships: $R = \sqrt{L/C}$, and $\Delta T \ll L/R$.

If it is desired to close the switch and maintain a constant current through R_0 for a short period of time ΔT in the series circuit of Fig. 3A, a choke and resistor are again inserted as in Fig. 3B. Equations are again identical with those for a discharging circuit, except that the right-hand side of Eq. 3 and 8 is E_0 instead of zero. This term disappears when Eq. 8 is differentiated. Thus the analysis is the same as before, and the same relationships hold.

Although it is not a resistor-capacitor circuit, the following analysis is included here because it is also a case of maintaining a constant current in an exponential circuit.

In a circuit including resistor, inductor, and battery as shown in Fig. 4A it is again desired to close the switch and maintain a constant current through R_0 for a short time ΔT. This result is accomplished by inserting a resistor and capacitor as shown in Fig. 4B. Just as before, and for similar reasons, ΔT must be short compared to the time constant of the inserted network. That is, $\Delta T \ll RC$.

Although the characteristics of this circuit are comparable to those of the resistor-capacitor circuit previously analysed, the mathematical

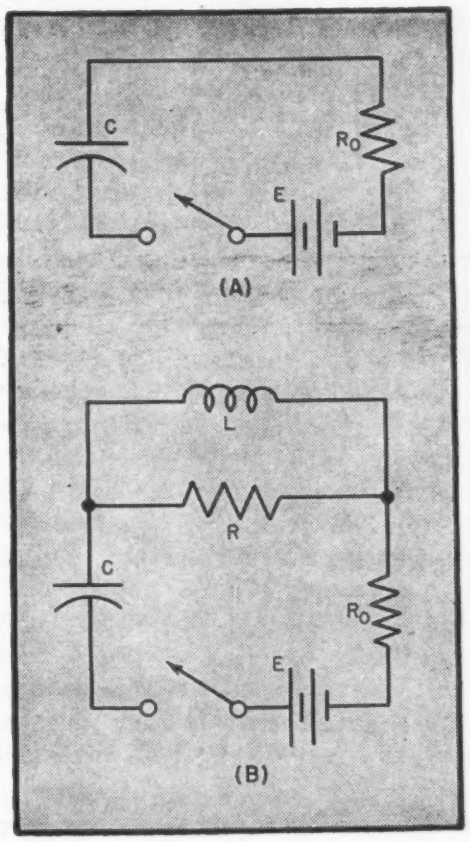

FIG. 3—Instead of discharging a capacitor, as in Fig. 1, the capacitor can be charged in the manner shown here

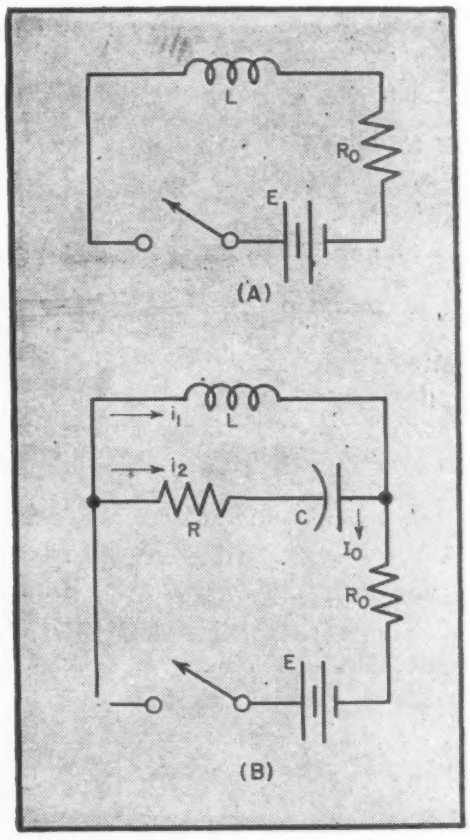

FIG. 4—(A) An inductor can replace the capacitor of Fig. 3. Corrective network (B) contains inductance

analysis for this resistor-inductor circuit is included here. As before, by Kirchhoff's Laws

$$L\frac{di_1}{dt} + I_0R_0 = E \tag{10}$$

$$R\frac{dq}{dt} + \frac{q}{C} + I_0R_0 = E \tag{11}$$

$$i_1 + i_2 = I_0 \tag{12}$$

From Eq. 10

$$\frac{di_1}{dt} = \frac{E - I_0R_0}{L}$$

From which by integration

$$i_1 = \frac{E - I_0R_0}{L}t + A$$

When $t = 0$, $i_1 = 0$, thus $A = 0$, and

$$i_1 = \frac{E - I_0R_0}{L}t \tag{13}$$

Likewise, from Eq. 11

$$q = B\epsilon^{-(1/RC)t} + (E - I_0R_0)C$$

As in the original circuit analysed, this simplification is permissible because $\Delta T \ll RC$. When $t = 0$, $q = 0$, thus $B = -(E - I_0R_0)C$, and

$$q = C(E - I_0R_0)\,(1 - \epsilon^{-(1/RC)t})$$

But $i_2 = dq/dt$, and therefore

$$i_2 = \frac{E - I_0R_0}{R}\epsilon^{-(1/RC)t} \tag{14}$$

Substituting the values of i_1 and i_2 given by Eq. 13 and 14 into Eq. 12 gives

$$\frac{E - I_0R_0}{L}t + \frac{E - I_0R_0}{R}\epsilon^{-(1/RC)t} = I_0 \tag{15}$$

Diqerentiating Eq. 15 gives

$$\frac{E - I_0R_0}{L} - \frac{E - I_0R_0}{R^2C}\epsilon^{-(1/RC)t} = 0 \tag{16}$$

During the short interval ΔT, $E - I_0R_0$ does not equal zero. Also, if ΔT is very small compared to RC, $\epsilon^{-(1/RC)t}$ is approximately unity. Therefore Eq. 16 reduces to the same relationship as previously obtained: $R = \sqrt{L/C}$. It should be noted that in this case, as before, the result is independent of the value R_0.

Magnetron Application

The circuit in Fig. 2 is similar to a discharge circuit used in some radar transmitters, and the load represented is essentially the equivalent circuit of a magnetron. The magnetron impedance is nonlinear, having a volt-ampere characteristic similar to that shown in Fig. 5. In general, the dynamic impedance is not constant over a wide range of voltage and current. However, over a small operating range the magnetron can be represented to a good approximation by the circuit shown in Fig. 6, consisting of a linear resistance equal to $\Delta E_M/\Delta I$, a perfect rectifier, and a battery E_0, where E_0 is the voltage intercept of a line drawn tangent to the curve at the operating point.

In one application the capacitor is charged between pulses through a resistance from a d-c source. The switch is a vacuum tube which is normally nonconducting but is turned on at regular intervals to discharge part of the stored energy into the magnetron in the form of rectangular pulses. With a constant magnetic field applied to the magnetron, the output frequency of the magnetron is a function of its peak current. Consequently, to prevent frequency shift during the pulse, it is important that the discharge current be maintained very nearly constant.

Of course, the current can be held nearly constant by making the capacitor C very large. However, high-voltage capacitors are physically large and heavy, and therefore present serious difficulty in aircraft sets where space and weight are at a premium. Addition of the resistance-inductance network permits the use of smaller capacitors for a given pulse duration, or with a given size capacitance the pulse generator can produce longer pulses. These advantages are best illustrated by numerical example.

First consider the case without the addition of the resistance-inductance network. The current is found by simple circuit analysis

$$i = \frac{E - E_0}{R_0}\epsilon^{-(1/R_0C)t} \tag{17}$$

Typical values are
$E = 14{,}000$ volts
$E_0 = 11{,}500$ volts
$R_0 = 200$ ohms
$C = 0.1$ microfarad

Thus

$$i = \frac{14{,}000 - 11{,}500}{200}\epsilon^{-(10^6/20)t}$$

At the moment of closing the switch the current is 12.5 amp. After one microsecond the current is 11.9 amp. This change represents a current drop of about five percent, which is barely tolerable with some magnetrons.

Now an R-L network is inserted, giving the circuit of Fig. 2 with $L = R^2C$. The resistance might be 50 ohms. The inductance must be 250 μh, and $(L/R) = 5 \times 10^{-6}$. By conventional circuit analysis the current as a function of time is found to be

$$i = \frac{E - E_0}{R + R_0}(1/2\beta) \times [(\beta - \alpha)\epsilon^{-(\beta + \alpha)t} + (\alpha + \beta)\epsilon^{-(\alpha - \beta)t}] \tag{18}$$

where $\alpha = 1/2RC$

$$\beta = \alpha\left[\frac{R_0 - 3R}{R_0 + R}\right]^{1/2}$$

At the moment of closing the switch the current is now ten amperes. After one microsecond it has fallen to 9.96 amp. In this case the current drop is less than 0.5 percent.

If it were desirable to maintain the same magnetron operating point as before with an average pulse current of approximately 12.2 amp, it is only necessary to raise the voltage on C to 14,550 instead of 14,000 volts.

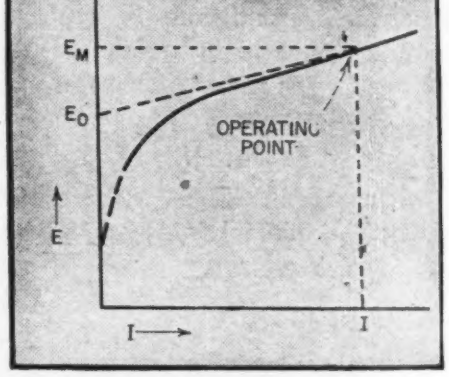

FIG. 5—Load characteristics of d-c anode circuit of magnetron can be simulated by battery and resistor

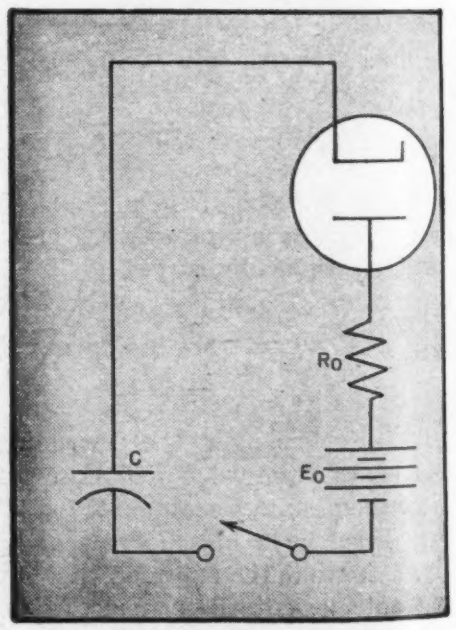

FIG. 6—An equivalent magnetron pulsing circuit containing a storage capacitor

The initial current is then 12.20 amp, and at the end of one microsecond $i = 12.15$ amp, still less than a 0.5-percent droop.

With the voltage raised to 14,625 volts, the initial current is again 12.5 amp, but it takes four microseconds for it to drop to 11.9 amp, the value reached in one microsecond without the addition of the resistance-inductance network. Thus the *R-L* network permits increasing the pulse length by a factor of four, provided the same percentage droop in current can be tolerated as for the shorter pulse.

If $C = 0.025$ μf and R remains 50 ohms, L must be 62.5μh. Then with $E = 14{,}625$ volts, the initial current is 12.5 amp, and at the end of one microsecond, $i = 11.9$ amp. Thus, for one microsecond pulse duration the capacitance can be decreased by a factor of four without causing a greater droop than was obtained without the *R-L* network.

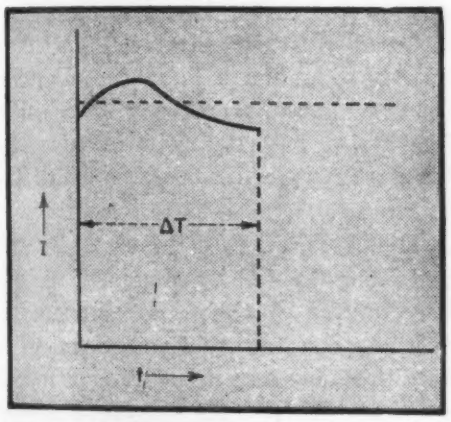

FIG. 7—Percent deviation from a constant level over a given time can be reduced by adjusting the corrective network

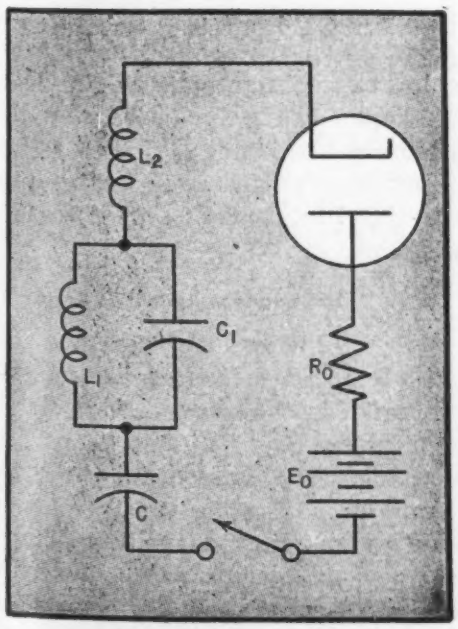

FIG. 8—A corrective network can be made entirely of reactive elements

It may be noticed that the values of L/R in all these examples do not perfectly satisfy the requirement that $L/R \gg \Delta T$, and that the assumption that $\epsilon^{-(R/L)t}$ equals unity for the duration of the pulse is not quite true. As a result, the current pulses are not constant but droop slightly. To fulfill this condition rigorously and also have $L = R^2C$, it would be necessary to choose higher values for R and L. Then this droop would be practically eliminated, but as R is increased, the power supply potential E must be increased, and the power loss in R becomes greater. In practice, the selection of values of R and L is a compromise between minimum current droop and minimum power loss.

The requirement that $L = R^2C$ is also not critical. When the condition $L/R \gg \Delta T$ is rigorously fulfilled, a value of L less than R^2C would cause the current to rise linearly during the pulse, whereas if L were greater than R^2C, the *R-L* network would not be entirely effective in minimizing the current droop. In some cases it may be better to choose L less than R^2C, and L/R of the same order as, or even less than, ΔT so that the current, although remaining within an allowable percentage deviation from a specified mean value, first rises and then falls as shown in Fig. 7.

Practical Design

By more comprehensive circuit analysis or by experimentation, values of R and L can be determined for any given set of conditions which will permit increase in pulse duration ΔT or decrease in the required value of storage capacitance up to a factor of eight or ten, with very small loss of power. To obtain best results, the choice of R and L can also be influenced to some extent by other practical considerations not mentioned here. For example, it is conceivable that under certain conditions stray capacitance across the pulse generator switch and across the magnetron may form a resonant circuit with L and give rise to undesirable postpulse oscillations. A compromise in the choice of R and L may be necessary to produce the necessary damping.

Work was done by B. Chance, R. M. Walker, and others at Radiation Laboratory and elsewhere on improvement in linearity of voltage rise across capacitors used in timing circuits, beginning in 1942. One method employed inductance in series with resistance and capacitance, with appropriate tube switching to select only a small, linearly rising portion of the exponential voltage. However, in these low-level circuits power loss is usually an unimportant consideration and magnitudes of resistance, inductance, and capacitance differ appreciably from those recommended by the preceding analysis.

For a treatment of linear timing circuits the reader is referred to the Radiation Laboratory Technical Series volume entitled "Waveforms" now being edited for publication. For a recent application of the parallel resistor-inductor network to improve linearity of high-speed sweep see Radiation Laboratory Report 1001 by D. F. Winter, and the as yet unpublished Radiation Laboratory Technical Series volume entitled "Cathode Ray Tube Displays".

Dissipationless Circuit

Another method for minimizing magnetron pulse current drop has been suggested both at Radiation Laboratory and elsewhere. A. A. Varela, Naval Research Laboratory, Washington, D. C., described the use of an *L-C* network composed only of passive elements L_1, L_2, and C_1, as shown in Fig. 8. The network is used in place of the parallel *R-L* unit. Such a network will accomplish the desired result but has the disadvantage of requiring one more circuit element including a second capacitor of medium voltage rating. Although this type of pulse-forming network is composed of lossless elements, the voltage drop during the pulse due to the network surge impedance causes an effective loss in pulse power which is comparable to losses in equivalent *R-L* networks. The energy remaining in L_1, C_1, and L_2 at the end of the pulse may be dissipated in post pulse oscillations. Therefore, in view of these considerations, it seems advisable for most applications to use the simpler *R-L* network.

This paper is based on work done for the Office of Scientific Research and Development under contract OEMsr-262 with the Radiation Laboratory, Massachusetts Institute of Technology.

Vhf Antenna For Trains

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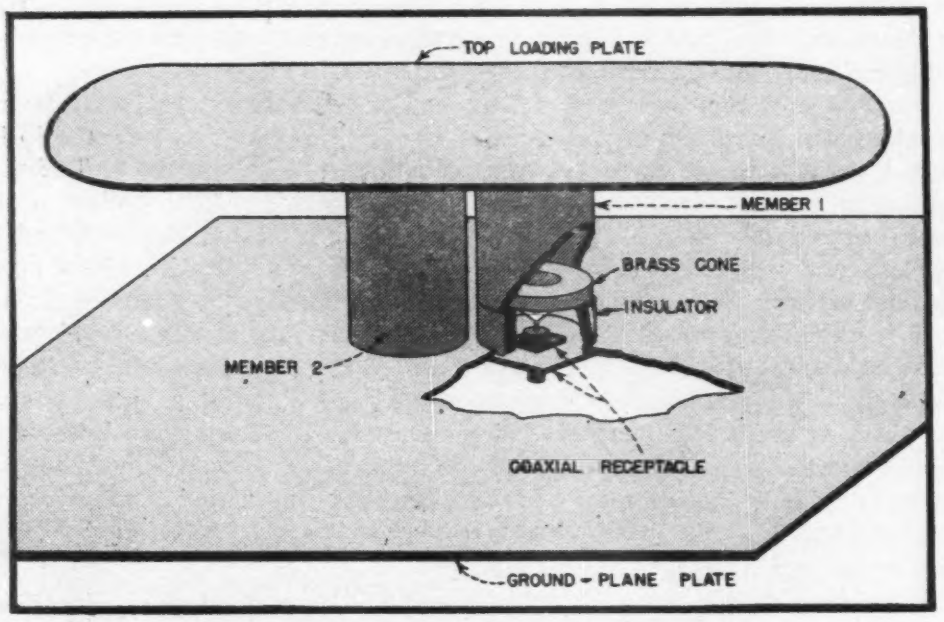

FIG. 1—Cutaway shows method of feeding antenna

AN ANTENNA for use in the 158-162 mc band on trains must satisfy several requirements. It should be essentially omnidirectional in the horizontal plane because the train may be oriented in any direction with respect to the various fixed stations with which communication is desired. The angle of radiation of the antenna should be kept as low as possible in order to get a maximum concentration of energy in the horizontal plane because the omnidirectional requirement prohibits concentrating the energy in one horizontal direction at a sacrifice in some other horizontal direction. The antenna should be sufficiently rugged mechanically that men walking along the top of the train can take hold of it for support without causing damage to it.

At the present writing, indications are that train antennas should be vertically polarized as audio modulation caused by the train moving past telephone poles and other structures along the right of way seems to be less troublesome for vertical than for horizontal polarization.[1]

Choice of Antenna Design

In order to get the maximum energy concentration in a horizontal plane, the most desirable type of antenna would be vertical colinear array placed as high on top of the train as possible. Because of the restricted clearances of most railroads this type of array is obviously impossible at these frequencies. The next best type of antenna is one that uses all of the available clearance and is tailored in dimensions and current distribution for the particular installation.

Two possibilities that exist are that of placing a relatively long vertical antenna on some low part of the train such as on the tender, or of placing a short vertical antenna on a high portion of the train such as on the engine cab. The chances are that, with the first possibility, reflections from adjacent parts of the train that are as high as part of the antenna would cause the radiation pattern to be far from omnidirectional and could quite easily cause the radiation to be concentrated in the least desired directions. Following the second possibility, an antenna was designed with such small height that it can be placed on top of a train that has approximately five inches of clearance.

Figure 1 shows the method of feeding the completed antenna. Because of corrosive fumes present behind a steam locomotive, the antenna is constructed of stainless steel. A rather wide base insulator is used to provide a long leakage path across the 50-ohm feed point in order to minimize the effects of soot deposited on the insulator.

The antenna is 5-in. or 24.3° tall and is top loaded by means of an oblong plate so that the current is nearly constant throughout the height of the antenna, being a maximum at the top. As shown, Member 2 is a steel pipe welded to the loading plate and to the ground plane, thus forming the second leg of a folded monopole. The folded type of construction was chosen for its mechanical strength and because it furnished a simple means for increasing the radiation resistance of the rather short antenna in order to facilitate the matching to a 50-ohm transmission line.

Impedance Relations

Figure 2 shows the phase and amplitude of the measured current distribution in the two members of the monopole. By changing the shape of the loading plate on top of the antenna it is possible to control this current distribution within limits. It was found necessary to extend the loading plate slightly farther on the side of the top fed member than on the side of the base fed member in

Top loaded, folded, vertically polarized, monopole antenna concentrates radiation close to the ground in an omnidirectional pattern. Antenna is only five inches high, mechanically rugged, and has an input impedance of fifty ohms. Design techniques are described

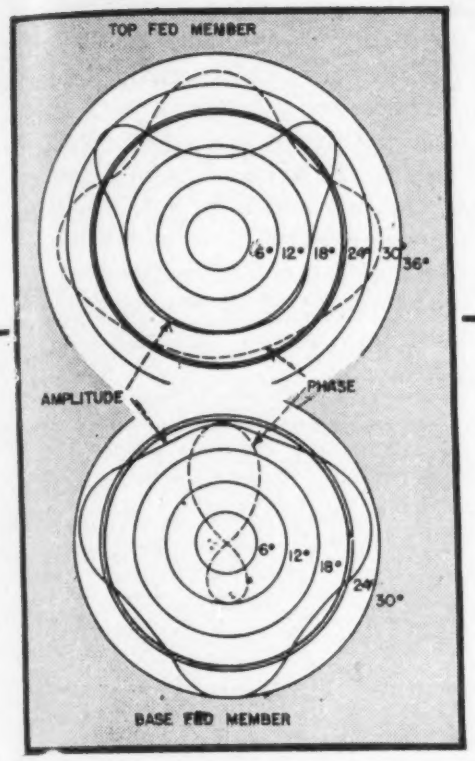

FIG. 2—Current distribution at base of antenna radiators

order to make the current approximately uniform around the two members.

Assuming that the radiation due to the current distribution is the same as that due to a thin filament of current located midway between the two members of the antenna and equal to the vector sum of an infinite number of filaments of which the actual current distribution can be considered as being composed, the radiation resistance measured at the bottom of the base fed element can be computed quite simply. This assumption is not rigorously correct because of phase differences between radiations of the various filaments in the actual distribution and also because of variations in the top loading of the different filaments, but is close enough to give a useful answer. A graphical determination of the vector sum of the current filaments in the actual distribution gives a current of 13.3 at plus 12.4° for both monopoles together and a current of 8.2 at 11.8° for the base fed member alone. The unit in which these currents are measured is not important as it cancels out in the resistance computations.

Where R_a is the radiation resistance of the imaginary filament at the center of the antenna which is considered as carrying all of the current, the power radiated by the whole antenna is $13.3^2 R_a$. The radiation resistance referred to the current at the feed point is the antenna power divided by the square of the current at the feed point[2] and is

$$(13.3/8.2)^2 R_a = 2.62\ R_a \qquad (1)$$

Antenna Feeding

Figure 3 shows the current distribution in a vertical plane of the antenna. It will be noted that the antenna is not fed at a current loop but is fed below the current loop. There are two reasons for this practice. One is that, by raising the position of the current maximum in an antenna of this type to a point near the top, it is possible to increase the radiation along the horizontal[3]. The other is that, due to the need for a large, rugged base insulator which shunts the feed point with a capacitance, it is desirable for purposes of matching to the transmission line to make the antenna slightly inductive. Feeding the antenna at a point below the current loop not only has the effect of making the antenna inductive, but also causes the radiation resistance to increase by a factor $1/\sin^2 G$ where G is the angular height above the base to the point at which the antenna current would reach a minimum if it were not suppressed by the top loading plate.[4]

The radiation resistance of the current filament referred to a current loop can be computed from the formula[4]

$$R_r = 30 \left\{ \sin^2 B\,[(\sin 2A/2A) - 1] - 0.5 \cos(2G) S_1(4A) + [1 + \cos(2G)] \times S_1(2A) + \sin(2G)\,[0.5\mathrm{Si}(4A) - \mathrm{Si}(2A)] \right\} \qquad (2)$$

where $G = A + B$, and A is the angular height of the antenna top above the ground plane and B is the angular height of suppressed radiation, and $S_1 = \ln X + 0.5772 - \mathrm{Ci}(X)$.

$$\mathrm{Si}(X) = \int_0^X \frac{\sin x}{x}\,dx$$

$$\mathrm{Ci}(X) = \int_\infty^X \frac{\cos x}{x}\,dx$$

This radiation resistance is 6.77 ohms. Referring this resistance to the base of the antenna gives $6.77/\sin^2 114.3° = 8.15$ ohms. Substituting this value in Eq. 1 gives 21.4 ohms. Because the value of G is greater than 90°, the antenna has an inductive component of 25 ohms at the base. The negative susceptance due to this inductive component is cancelled by the positive susceptance due to the capacitance of approximately 43 ohms across the bakelite insulator at the base of the monopole as seen in Fig. 1. The equivalent circuit of the feed point is shown in Fig. 4. It is the circuit of a parallel resonant circuit of extremely low Q. The input impedance of the antenna is therefore the parallel resonant impedance of this circuit and is a pure resistance of 50 ohms.

In the actual development of the antenna, preliminary calculations were made assuming an increase of radiation resistance due to the folding of the monopole of three over R_a rather than the 2.62 finally obtained. The amount of top loading required to give the desired vertical current distribution was determined experimentally • by sliding three metal plates over each other until a value of total current with respect

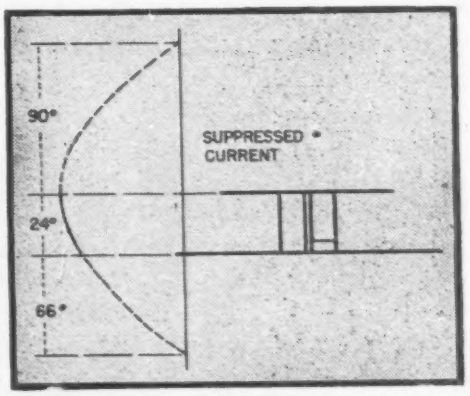

FIG. 3—Vertical distribution of antenna current

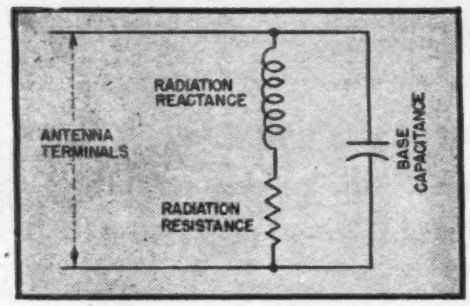

FIG. 4—Equivalent circuit of antenna as seen from its input

to current in the base fed member was found for which there existed a single value of base capacitance that would make the antenna resistive at the same time that its impedance was 50 ohms. The standing wave ratio of the antenna taken on a 50-ohm line is shown in Fig. 5. The impedance match is affected by the size of the ground plane and with the 30- by 30-in. steel plate for ground, the standing wave ratio is 1.1 to 1.0.

Radiation Pattern

As may be expected, the effect of the ground plane is very great on the radiation pattern of the antenna. Figure 6A shows the vertical radiation pattern with only a 30- by 30-in. steel plate as a ground plane. Figure 6B shows the radiation pattern taken with a 6- by 6-ft. screen as a ground plane. Figure 6C shows the radiation pattern with an infinite ground (taken by mounting two identical antennas base-to-base on a rotating pedestal, thus replacing the image of one antenna in the ground by an actual antenna). Also shown on Fig. 6C is the theoretical pattern computed from the current distribution of Fig. 3[4].

The horizontal radiation pattern of the antenna is nearly circular with the radiation in a direction at right angles to a plane formed by the two members of the monopole being ten percent less than that in the direction of their plane.

The problem of obtaining directivity in an antenna to be used atop a train is rather difficult because the least space is available in the direction in which it is the most needed, namely, the vertical. Antennas of the type described in this paper are nice mechanically but their only claim to concentration of energy into the vertical plane is that they get the current maximum as high above the train as possible. The possibility exists of placing several such top loaded antennas atop a train in the form of an array to give greater directivity when communication is to be carried on with a station or stations in a constant direction with respect to the axis of the train. An array of extremely high directivity could be obtained by placing many such antennas along the top of the train in the form of an

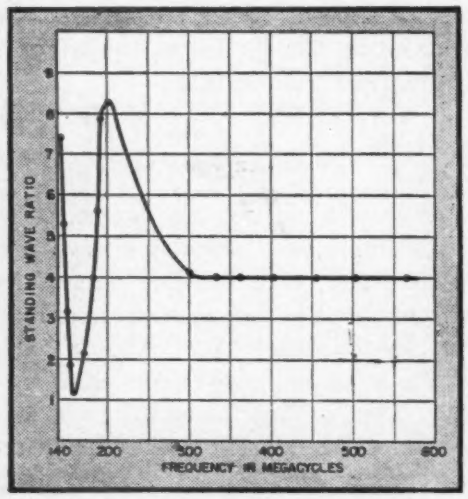

FIG. 5—Standing-wave ratio produced on a 50-ohm line by the antenna

end-fire array and switching the transmitting and receiving equipment to this array when the train is going to be on a stretch of straight track for many miles.

It is difficult if not impossible to predict what the pattern of a single antenna will be when placed atop trains in which space for a ground plane is limited. The most obvious recourse is to investigate, by field measurements on the train itself, the direction in which energy is radiated. The patterns of Fig. 6A and 6B indicate that greater signals are obtained along the horizontal with the smaller ground plane. This result is probably because the 30- by 30-in. ground plane was so small that it did not prevent antenna currents from flowing in the column on which the antenna was mounted during test.

The curve of Fig. 6C is calculated on the assumption that there is no radiation from the top loading plate. This assumption is not valid because the loading plate is an appreciable portion of a wave length long, and even if the current distribution in the plate were symmetrical about the two axes of the plate, radiation from the plate would be zero only in directions normal to the plate. The currents in the vertical members of the antenna as shown in Fig. 2 indicate that the distribution in the loading plate can not be symmetrical so that radiation should be expected even in directions normal to the loading plate.

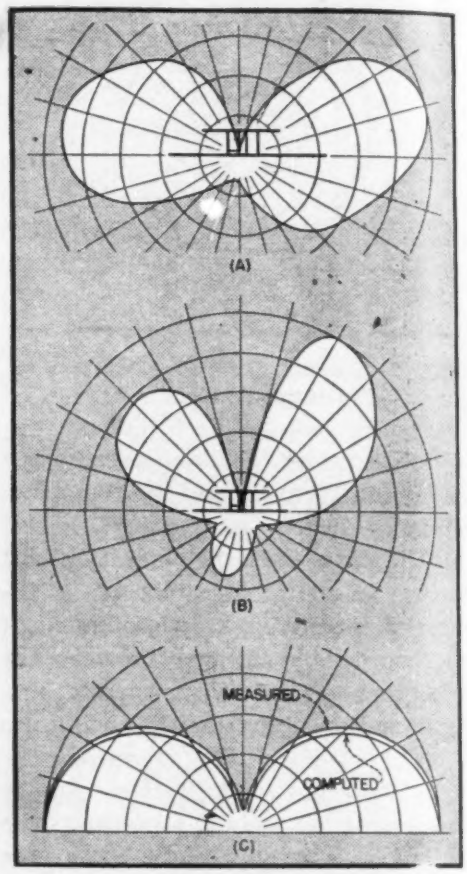

FIG. 6—Vertical radiation pattern of antenna with (A) a 30-in. square ground plate, (B) a 6-ft. square ground plate, and (C) an infinite ground plate

There are of course many manners in which the impedance of an antenna of this type could be matched to the transmission line. One of the most obvious would be to use top loading such that the value of G would be 90° and then use a top fed member of such diameter that the radiation resistance of the combination would equal the characteristic impedance of the transmission line.

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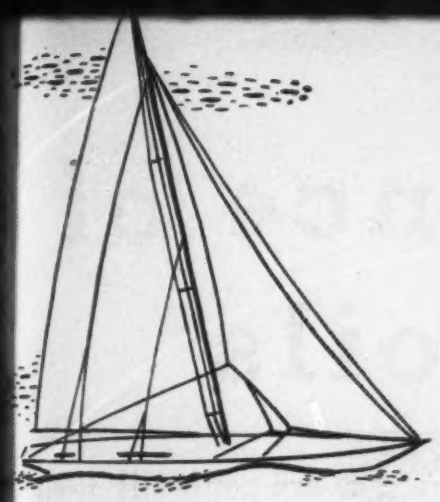

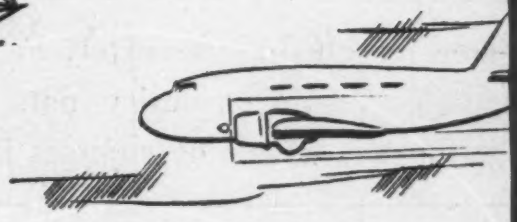

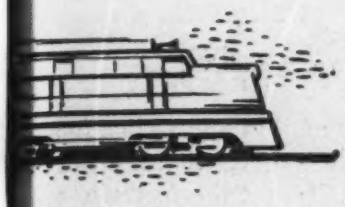

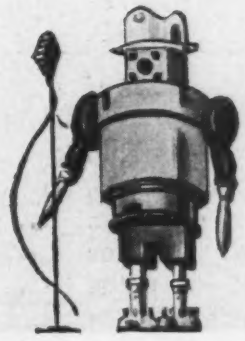

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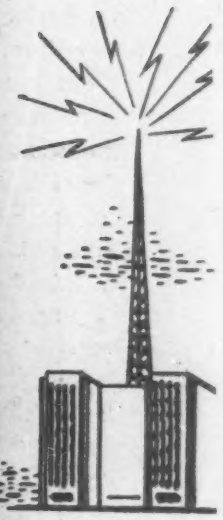

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Mutual Inductance of Concentric Coils

For air-core transformers with greater length than diameter, such as are generally used in r-f service, this nomograph provides pertinent design data in three settings of a straightedge and clearly shows the effects of changes in parameters

By THOMAS C. BLOW

Massachusetts Institute of Technology
Cambridge, Mass.

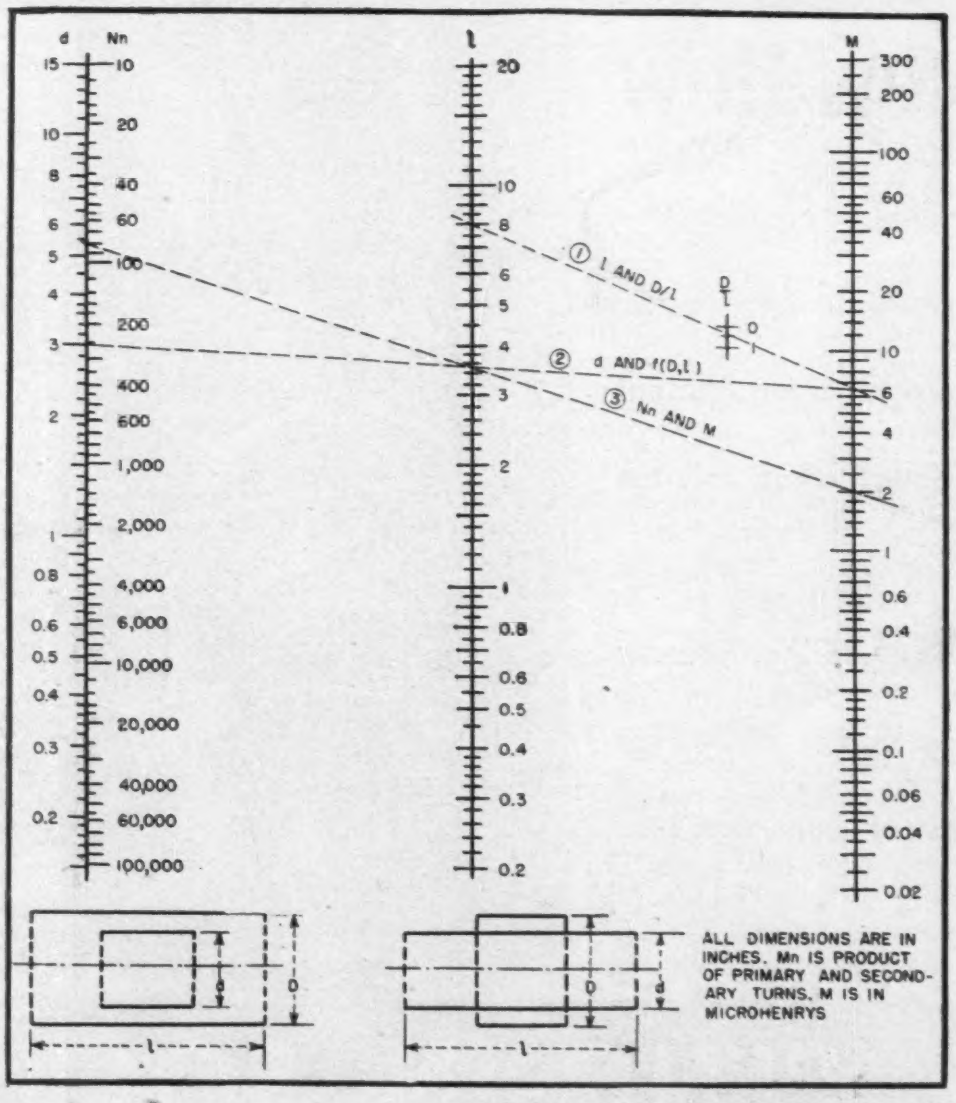
MUTUAL INDUCTANCE between two concentric single-layer air-core solenoids is a circuit value that defies simple analysis. Mutual inductance is dependent on coil dimensions in such an involved manner that design of a radio-frequency transformer is difficult. This nomogram facilitates the design of these transformers.

Examination of the relationship for coaxial solenoids (Circular C74, National Bureau of Standards, Jan. 1937, p 281-282) reveals that for values of D/l less than unity the formula reduces approximately to

$$M = 0.0251 \frac{d^2 Nn}{(D^2 \times l^2)^{1/2}}$$

The accuracy of this approximation is within three percent for most conditions. From this formula a simple nomograph, which allows an investigation of the effects of the parameters, can be plotted. For given coil dimensions, M is directly proportional to the product of primary and secondary turns. For a given value of d, the outer diameter D does not greatly influence the mutual inductance, and the length of the shorter coil has no effect on the mutual inductance.

To show the use of the chart, consider a design where the outer coil is to be the shorter. Choosing l as 8 in., d as 3 in., and D as 4 in., draw a line (1) through $l = 8$ and $D/l = 0.5$ extending to the M scale. Connect this intersection on M to $d = 3$ with a straight line (2). Use the resulting intersection with the l scale as a turning point for selecting compatible values of Nn and M, draw a straight line (3). If, as shown, the mutual inductance is to be 2 mh, the turns product should be 80. With 16 turns on the longer coil, 5 turns would be required on the shorter one. It should be noted that the 5 turns can be wound with any spacing without materially changing the value of M. The chart can be used to determine any one of the variables l, d, D, Nn, or M when the others are known as long, as the sequence of operations is preserved, namely 1,2,3 or 3,2,1.



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(Above) *The Udylite Mallory Rectoplater* UM-1500A, one of a complete line of DC Power Supply Units manufactured by Mallory. It incorporates Mallory Rectifier 6 SPR 750 illustrated at the top.*

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TUBES AT WORK

Edited by VIN ZELUFF

Pulse Time Modulation Circuits 140
Reactance Comparator 142
Modulated Arc Lamp 150
Two-Station Antenna System 154
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New Station Techniques 168
Speeding Up the Return Trace 176

Pulse Time Modulation Circuits

CIRCUIT DATA on pulse time modulation (ELECTRONICS Jan. 1945 p 100) has been released by Federal Telecommunication Laboratories at a recent demonstration. The method of multiplexing involves the transmission of a series of pulses, each about 0.5 microsecond, which are modulated by varying the time interval between pulses. At the receiver, proper selection of the pulses is made by simple timing circuits so that several channels can be transmitted on a single carrier.

The transmitting equipment demonstrated takes eight modulating signals from several studios at line level over an audio-frequency range of 50 to 9000 cycles per second. Eight sequences of pulses, derived from a common pulse generator, are individually time-modulated by the corresponding programs, interleaved with a sequence of marker pulses, and fed to the r-f modulator for further amplification and keying of the 930-megacycle oscillator. The output of the transmitter is approximately 800 to 1000 watts peak and 40 to 50 watts average. This is fed to a vertically stacked loop antenna having a gain of 9 decibels over a dipole throughout 360 degrees in a horizontal plane.

A block diagram of the system is shown in Fig. 1. The multiplex modulator consists of a sawtooth pulse generator, a delay line synchronizer, an audio amplifier for each channel, a time modulator for each channel, a marker pulse shaper, and a mixer shaper.

The 9,000-cycle audio fidelity is assured by the use of a 24-kc sawtooth pulse generator, and the basic timing of the pulse channels is obtained by a series of stable time delay elements, tapped at nine successive points. By this method, nine pulse sequences are produced, each having the basic 24-kc repetition rate, but displaced from the previous sequence by an equal time interval.

One pulse sequence is fed to the marker pulse shaper which generates a double pulse for use as a time reference base in separating the various programs at the receiver. The remaining eight sawtooth pulse sequences are fed to the corresponding time modulators of each program channel where they are converted to rectangular pulses varying in time displacement, relative to the marker pulse, in accordance with the applied audio signal.

After time modulation and marker shaping, the nine pulse sequences are interleaved and fed to the mixer shaper for further amplification and improvement of pulse shape. From here the pulses are transmitted at a peak level of five volts over 70-ohm solid dielectric coaxial transmission line to the r-f transmitter. The repetition rate of the combined pulse sequence is 9 × 24 kc or 216 kc.

R-F Section

The r-f transmitter consists of a modulator and an oscillator. The modulator is a wide-band pulse amplifier raising the time-modulated pulses from five volts to approximately 300 volts for grid keying the 930-mc oscillator. The latter contains an air-cooled uhf triode type 2214-B which is tuned by an auxiliary resonant coaxial-line element. Single-control tuning is provided within the operating range of 920 to 940 mc and pretuning to this frequency range is accomplished by adjustable shorting sections in the resonant transmission line elements. The oscillator has high inherent frequency stability so that further stabilization is omitted in the experimental equipment.

A calibrated frequency meter mounted on the control panel is provided for monitoring purposes, and oscilloscope jacks are available for examining the pulse output characteristics. An output power detector can be used in routine maintenance checks.

Receiver Circuits

The directive receiving antenna consists of a double dipole at the focal point of a parabolic reflector. This has a gain of 17 db in the re-

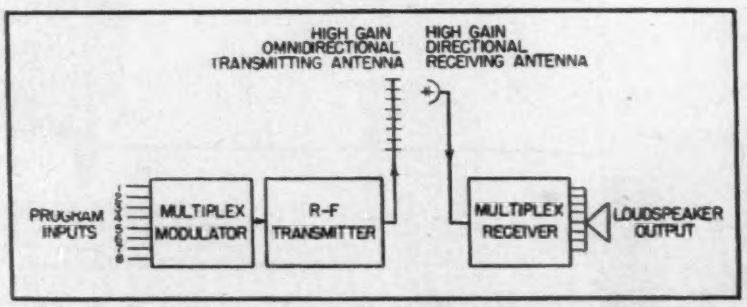

FIG. 1—Basic portions of Federal's pulse time modulation system. Use of the omnidirectional transmitting antenna permits broadcasting services

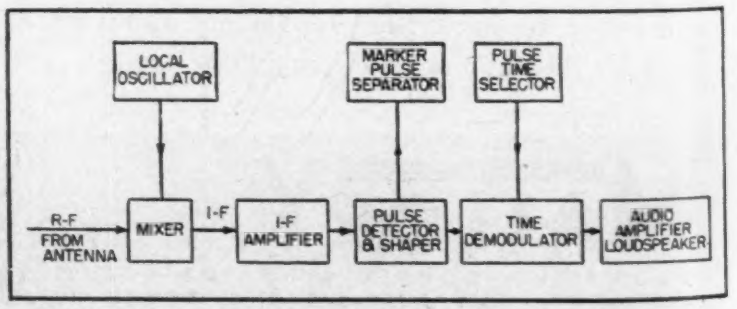

FIG. 2—In the receiver, pulses are separated and sorted to provide eight 9,000-cycle audio channels and/or audio, facsimile, and telegraph services

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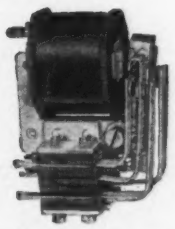
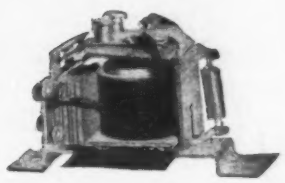


SERIES 40 A C
LAMINATED RELAY



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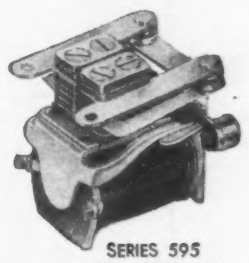
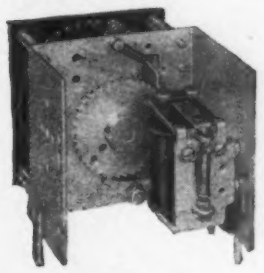


SERIES 595
MIDGET RELAY



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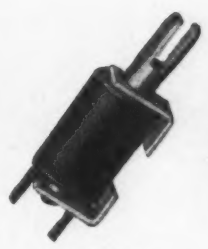
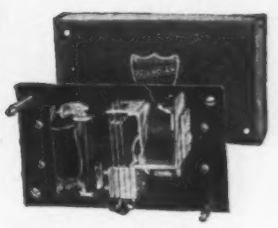


SERIES 1-A
SOLENOID



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ceiving direction. The receiver is fixed tuned and, as shown in Fig. 2, its circuit is conventional in the front end with a local oscillator, a mixer, and an i-f amplifier. To these are added a pulse detector and limiter, a marker pulse separator, a pulse time selector, and a time demodulator that acts as the audio detector. A type 1N28 crystal is used in the mixer, and a broad i-f bandwidth is provided to pass the pulse frequencies. This also aids in stability requirements and minimizes regeneration.

The pulse detector is of the conventional amplitude type and includes clipping and shaping of the pulses for further signal-to-noise improvement. The pulses are then passed on to the audio detector which performs two functions, time selection of the desired pulse channel, and its demodulation to give the audio program output.

Delayed Marker Pulse

The marker pulse is separated from the channel pulses by means of its double pulse characteristic and fed to the pulse time selector. Here it is delayed in timing, by an amount which depends upon the setting of the selector switch, so as to coincide with the desired channel pulse sequence. The delayed marker pulse is then fed to the time demodulator along with the combined program pulse sequences. Operation of the time demodulator or audio detector tube is controlled by the delayed marker pulse so that it functions only at those instants of time corresponding to the arrival of the desired program pulse sequence. The detected program signal is then fed to the audio amplifier and loud speaker or associated terminal gear in the case of special services.

Eight time demodulator sections connected to the different switching points in the pulse time selector section permit all programs to be received simultaneously and distributed for ultimate selection by a number of audio speaker sections, and/or terminal equipment for facsimile and various types of telegraphic services.

Since each channel has a bandwidth of 9,000 cycles, and since telegraph circuits require only about 200 cycles for 60 word-per-minute transmission, the use of tone filters enables the number of sub-channels for such use to be multiplied. Therefore either the whole width of each channel may be used for high-fidelity sound, or a considerable number of telegraphic services may be sent over it.

In last year's demonstration of 24-channel ptm, electronic switching involving cyclophon cathode-ray tubes was used to assemble the pulses in correct sequence at the transmitter and sort them out at the receiver. The nonelectronic LC delay lines used in place of switching tubes in the latest demonstration utilize techniques developed during the war for radar pulse circuits, and illustrate emphatically that the efficiency and success of pulse time modulation does not hinge on specially designed switching tubes. Still other ways of assembling and sorting pulses are being tried by I.T.&T. engineers, with many offering promise of future useful application.

Reactance Comparator

RAPID COMPARISON of inductors, capacitors, or combinations of the two is accomplished by the Mervyn reactance comparator. Basically it consists of two similar circuits containing inductance and capacitance. One circuit forms part of a very stable oscillator while the other is a high-Q resonator, the two being very loosely coupled.

The natural frequency of the resonator is varied about the mean figure in synchronism with a pointer vibrating in front of a scale. At the instant when the resonator's natural frequency equals that of the oscillator, the scale is illuminated by a brief flash of light from a neon lamp. This action is repeated at the line frequency so that when the two circuits are equal the pointer appears to remain still due to the stroboscopic effect.

The basic circuit of the instrument is shown in Fig. 1. A dynatron oscillator is used as the standard since it will oscillate readily with any combination of inductance and capacitance, has high dynamic resistance at its resonant frequency, and does not require a tapped or double-wound coil because it is a negtive-resistance oscillator. The natural stability of the output is increased by coupling it to an amplitude limiter consisting of a diode which rectifies some of the dynatron output and uses it to reduce the oscillator's cathode current to a level determined by the setting of the delay bias on the diode.

The resonator circuit is similar to that of the oscillator except that the amount of negative resistance supplied by the dynatron tube is controlled manually to a point where the Q of the LC circuit is high, but is below the self-oscilla-

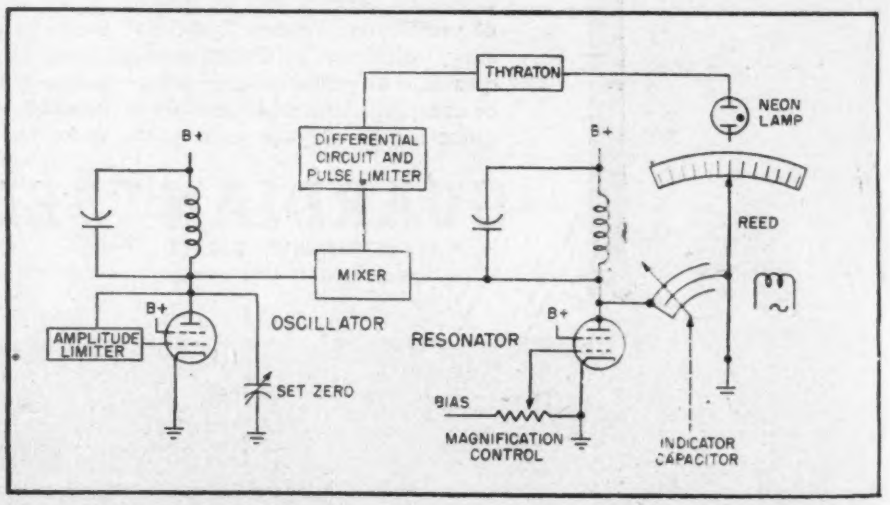

Fig. 1—Essential stages of the reactance comparator. Within its useful range, inductance can be checked against a standard with an accuracy better than one percent, and capacitance within 0.1 percent

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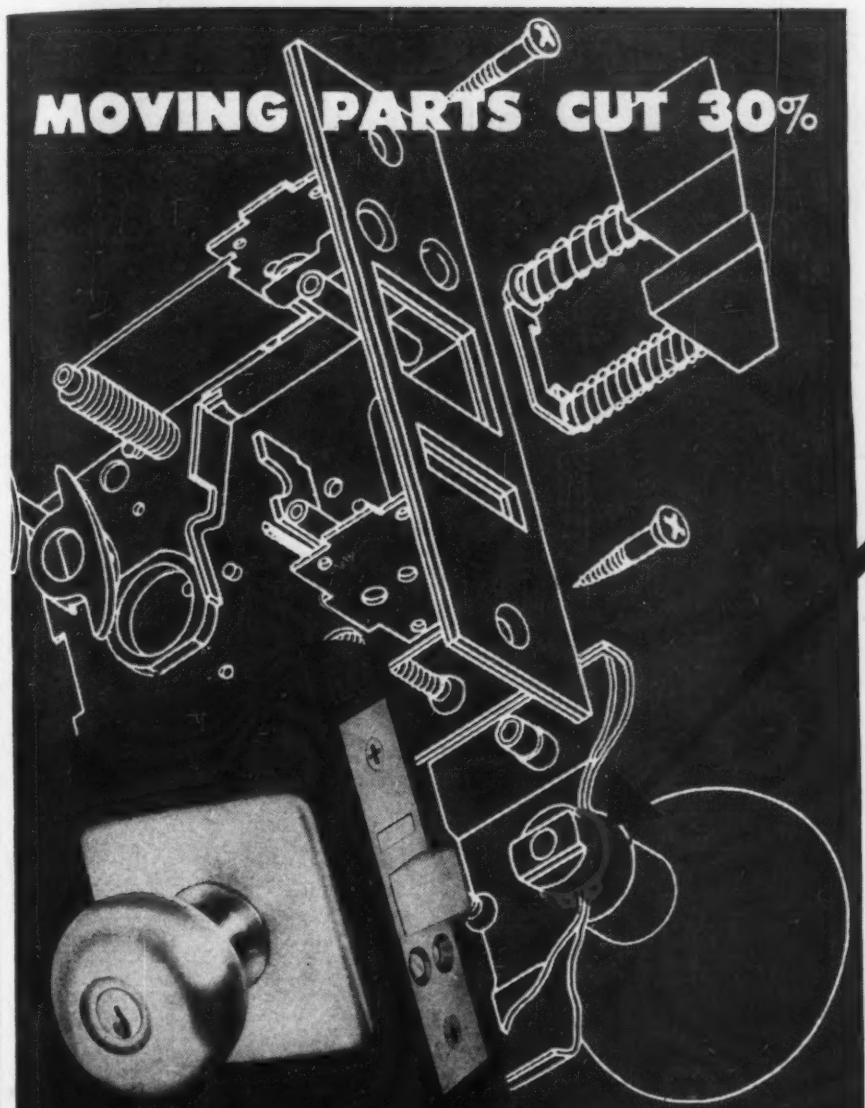

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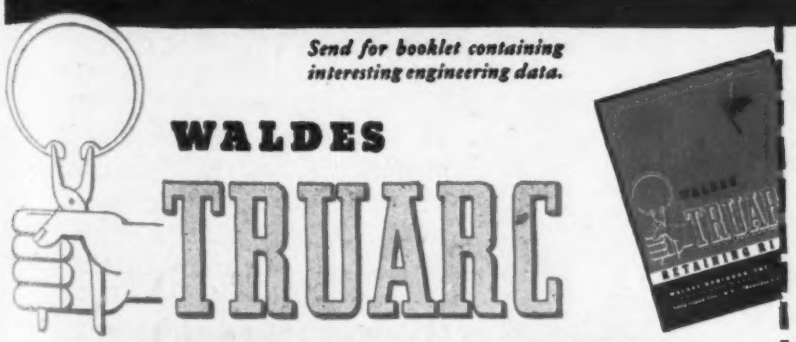

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tion point. The natural frequency of the resonator is varied by a small special capacitor, the moving element of which is carried by a tuned reed vibrating at the line frequency. A pointer is attached to the reed and moves over a short scale. Its movement is magnified by lenses.

Vanes as Capacitor Plates

The shape of the special capacitor vanes is very important and is determined by the main use to which the comparator will be put. Figure 2 gives some typical shapes. Shape *A* gives a linear capacitance scale, shape *B* gives a nearly linear scale of frequency if capacitance values are correctly chosen, shape *C* gives an approximately exponential scale and if used with negligible shunt capacitance will give a linear frequency scale, shape *D* gives an inductance or capacitance scale which is open in the middle and closed at the ends so that large tolerances can be indicated.

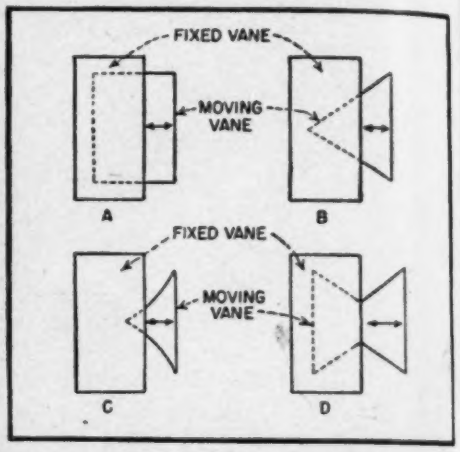

Fig. 2—Different vane shapes determine whether the scale of the special indicator capacitor is linear in frequency and capacitance or exponential

The oscillator is coupled to the resonator so that an alternating potential appears across the latter, its amplitude varying as the resonator is tuned relatively to the oscillator by the indicator capacitor.

When the resonator frequency is the same as the oscillator frequency, the relative phase angle of the alternating potentials in the two circuits changes suddenly and, as both circuits are connected to the mixer tube, its anode current is partially dependent on the two phase angles and changes sharply when the two frequencies are equal. This change is differentiated to

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ACCURACY—0.5 DB.
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produce a positive and negative pulse, one of which is clipped, shortened and then used to fire the thyratron, which in turn passes current to produce a flash in the neon lamp of about 50 microseconds.

It might appear that by utilizing both pulses on the forward and return traces, a brighter indication could be obtained with a given scheme of illumination. In practice, however, this has not been found to be successful, since small phase shifts occurring in the various circuits are liable to cause double images to be produced.

A tuning eye indicator is used to check that the oscillator is working to set the magnification of the resonator. To do this the magnification control is turned until the indicator tube shows that the resonator is actually oscillating, then the control is reversed until oscillation stops.

Under production conditions the instrument permits a comparative check of inductance against any standard from 100 μh to 100 mh, with an accuracy better than one percent. Resonant circuits can be checked and preset for frequency; coils with short-circuited turns and broken strands in Litz wound coils are clearly indicated, thereby giving a ready production check for minimum Q. In addition, a comparative check of capacitance can be made up to 0.001 μf. The capacitance difference, plus or minus, can be read directly in $\mu\mu$f to an accuracy of 0.1 $\mu\mu$f or 0.1 percent, whichever is the greater. The instrument is made in England.

Modulated Arc Lamp

A CAESIUM VAPOR lamp for modulated infrared-ray communication was ready for use at the end of the war for convoy duty and troop landing operations. For peacetime use, it may prove useful for confidential ship-to-shore conversations, plane-to-ground or plane-to-plane communications, or in disaster areas where telephone wires are down and static makes radio communication impractical.

As accepted by the Navy, the

Model 315 Signal Generator. Designed down to the most minute detail for highest accuracy, greatest stability, minimum leakage, and good wave form $67.35

Model 305 Tube Tester. Tests all tubes. Provides for filament voltages from .5 volts to and including 120 volts. Spare sockets for future tube developments....$46.25

Model 260 High Sensitivity Set Tester. 20,000 ohms per volt. D.C. Voltage ranges to 5,000 volts A.C. and D.C. Resistance ranges to 20 megohms. Current ranges to 500 milliamperes.....$38.95

This Simpson "Big 3" . . . gives servicemen a real profit-making set-up

● The successful radio serviceman today must have the finest in test instruments for a very practical reason—that's his only hope of present and continued profits. To meet the tremendous volume of business available he must be able to "trouble-shoot" fast and *accurately* every time. Only thus can he correct trouble speedily, with satisfaction to the customers.

Simpson offers you, in three basic test instruments, the accuracy and advanced electronic engineering which have given Simpson the proudest name in the industry. They are tried-and-tested examples of the kind of instruments Simpson has always built. Their use will demonstrate that from Simpson alone can you expect "instruments that stay accurate" with construction and design that lead the field.

To dealer and to serviceman alike, Simpson offers today the assurance of continued profits that only quality can give. No Simpson instrument is ever marketed, or ever will be, unless its makers feel that, of its kind, nothing finer can be produced.

Simpson

INSTRUMENTS THAT STAY ACCURATE

SIMPSON ELECTRIC COMPANY
5200-5218 West Kinzie Street, Chicago 44

at ARNOLD THERE IS

NO CEILING ON QUALITY

We are not satisfied merely to offer you magnets which come up to the proposed R.M.A. standards . . . this is our minimum requirement. A quality floor below which we refuse to go.

Nor are we satisfied that ordinary production and inspection methods offer you adequate quality protection . . . we *individually test* each Arnold magnet in a loud speaker structure before shipment.

Another "individual touch" which has contributed to winning industry-wide customer acceptance for Arnold magnets is our established minimum standard of 4,500,000 BHmax for Alnico V material.

Over five million Arnold loud speaker magnets of the R.M.A. type have been produced since V-J Day under these quality safeguards. Continued adherence to them assures you of long-lived, dependable product performance.

In the mass-production of magnets, the Arnold "individual touch" does make a difference. Let us give you the whole story.

THE ARNOLD ENGINEERING COMPANY

SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION

147 EAST ONTARIO STREET, CHICAGO 11, ILLINOIS

Specialists in the manufacture of ALNICO PERMANENT MAGNETS

lamp produces its radiation from an arc stream three inches long and more than an inch in diameter. The inner bulb contains the arc in an

Norman C. Beese, research engineer at Westinghouse Lamp Division, demonstrates the caesium vapor lamp he designed for talking over an invisible infrared light beam

atmosphere of argon and caesium vapor. Space between this bulb and an outer bulb is evacuated. The life of the lamp is about 100 hours.

Direct current is used to maintain the arc in the Westinghouse lamp. Modulation of 100 percent is possible at some points in the audio range from 200 to 3,000 cycles. The lamp is mounted in a parabolic reflector on a ship's mast and a similar parabolic unit contains the photoelectric cell used in the receiver. The beam spread is about 25 degrees.

Cooperative Two-Station Antenna System

BY LINDSAY MCMANUS

Installation Engineer
Canadian Marconi Company
Montreal, Canada

A BROADCAST STATION that is probably unique has just been completed by Canadian Marconi Company at Sherbrooke, Quebec. It is, in fact, a combination of two stations—CHLT and CKTS.

CHLT has been operated by the

29 DIFFERENT RECTIFIER TUBES *Now Replaceable—*

WITH THE FEDERAL SELENIUM RECTIFIER

(No. 403D2625)

—FIRST OF ITS KIND IN THE INDUSTRY!

NO less than *twenty-nine* different types of rectifier tubes are now replaceable with Federal's new, miniature, 5-plate rectifier. Available now, this replacement is also an *improvement!* For not only does it subtract from your own manufacturing costs, it adds to product quality as well . . . and to consumer satisfaction. Here's how:

- **Saves space — only 1¼ x 1¼ x 11/16 inches — fits where tube won't**
- **Costs less than tube and socket it eliminates**
- **Long life — built to last the life of the set**
- **No warm-up period — starts instantly, runs cooler**
- **Installed in less time than tube — only two soldering jobs**
- **Sturdy, all-metal construction — not easily damaged**
- **Withstands overloads — even when charging deformed electrolytic condensers**

Every one of Federal's line of "Center Contact" Selenium rectifiers is designed to give the full measure of performance that have made them the standard of the industry. A Federal engineer will show you how to put this latest model into your circuits. Write for details to Department F 413.

Replacement for these Tubes:

5T4	5Y3	6Y5	25Z6	50Y6
5U4	5Y4	6Z5	35W4	50Z7
5V4	5Z4	12Z5	35Z3	117Z3
5Z3	6X5	7Y4	35Z4	117Z6
5W4	0Z4	12Z3	35Z5	0Y4
5X4	80	25Z5	35Z6	

Electrical Characteristics:

Maximum RMS Voltage	130 Volts
Maximum Inverse Voltage	380 Volts
Maximum Peak Current	1200 ma.
Maximum RMS Current	325 ma.
Maximum DC Output	100 ma.
Approximate Rectifier Drop	5 Volts

Two Federal Miniature Rectifiers in a voltage doubler circuit give 250 volts and 80 milliampere output from 117 volt AC power source.

Federal Telephone and Radio Corporation

In Canada:—Federal Electric Manufacturing Company, Ltd., Montreal
Export Distributor:—International Standard Electric Corporation, 67 Broad St., N. Y. C.

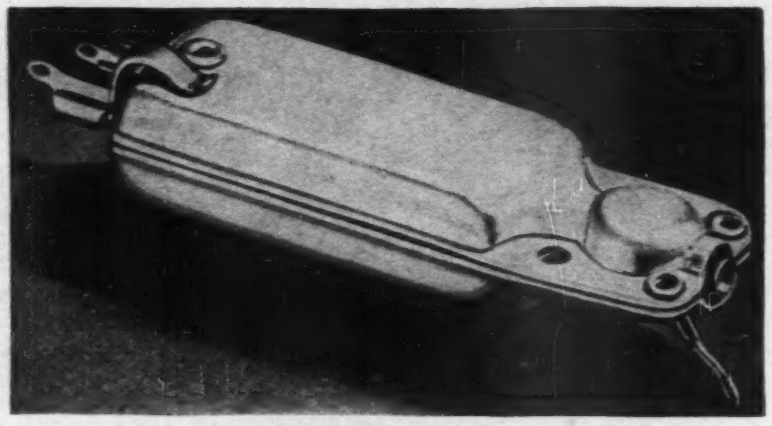
An IT&T Associate

Newark 1, New Jersey

4.2 VOLTS OUTPUT*!!

DIRECT CONNECTION TO PENTODE OUTPUT TUBES!

. . . and only 1⅛ oz. needle force



WITH THE NEW SHURE

W56A

Lever-Type Crystal Pickup Cartridge

List Price $4.45

AND

THE NEW SHURE

96A

Crystal Phonograph Pickup

List Price $6.10

MADE POSSIBLE THROUGH THE SHURE LEVER SYSTEM • HERE'S HOW IT WORKS:

The crystal is driven by a lever which improves the transmission of needle chuck torque into the crystal. This results in higher output and greater needle compliance. High needle compliance gives a "freedom of action" flexibility to the needle that means faithful tracking, and clearer, fuller tone qualities.

The lever arrangement absorbs the full impact of sudden jars to the cartridge or needle; this in turn gives relative shock immunity to the crystal—minimizing strain or breakage.

WHAT THE 96A DOES FOR YOU: It makes possible the saving of one stage of amplification, and it permits the use of a long-life precious-tip needle with a high-output pickup. Such a light-weight tone arm means that the records and needles will last much longer. The 96A "Glider" is less susceptible to floor vibrations, improves the playing of warped records, and is especially suitable for Vinylite records.

(*) 1000 cycle Audiotone record level using Full-Tone needle. About 3.5 volts using flexible needles. Voltage output on peaks reaches 40 volts!

WRITE FOR NEW CATALOGS 155 and 156

Patented by Shure Brothers and licensed under the Patents of the Brush Development Company

SHURE BROTHERS, INC.

Microphones and Acoustic Devices

225 West Huron Street, Chicago 10, Illinois
Cable Address: SHUREMICRO

SHURE

French-language daily newspaper, *La Tribune,* on 1,240 kc. An associated English-language weekly paper, the *Sherbrooke Telegraph* has now taken over this station and the call letters have been changed to CKTS. The *La Tribune,* still retaining its call letters—CHLT—has expanded to 1,000 watts and moved along the dial to 900 kc.

The original CHLT studio has been dispensed with and modern combined studios have been constructed for the two stations. Each station has its own control room facing the main studio with a master control room in between. Local programs and remote pickups are fed through the master control room and thence to either or both transmitters via the separate control rooms.

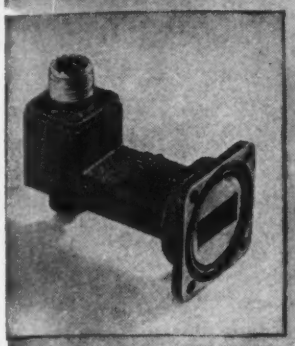
When CHLT was assigned its new frequency, it was with the provision that two other stations on the same frequency be protected at night. Daytime operation could be at 1,000 watts, omnidirectional, but it was necessary to change to directional operation at sunset.

Common Antenna System

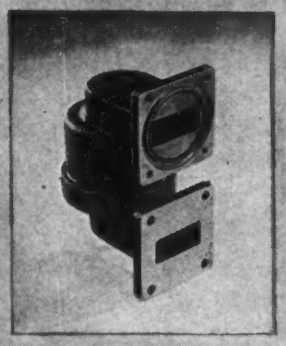
It was desirable to use the existing transmitter building for the two transmitters, having them and their associated audio and monitoring equipment in the same room, and to use the same antenna system for both stations. These plans presented problems in meeting all requirements and regulations and particularly to avoid any interaction or cross modulation throughout the entire audio and radio frequency circuits. Adequate shielding of audio components and lines would take care of this section, but r-f interaction between the two transmitters in the same room and using a common antenna could not be so easily avoided.

A new ground system for a two-tower array was put in and a new 196-foot guyed tower was erected. The existing tower of the same height was moved to a new location to form the directional array. The towers were spaced 120 degrees apart at 900 kc, and it was decided that the desired directional pattern could be obtained by a phase difference of plus 141 degrees with a 1.3 to 1 current ratio in the towers. During the entire process of in-

EVERY DE MORNAY-BUDD WAVE GUIDE
is Electrically Tested, Calibrated and Tagged

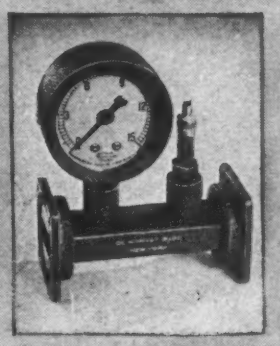


Crystal Mount DB-453

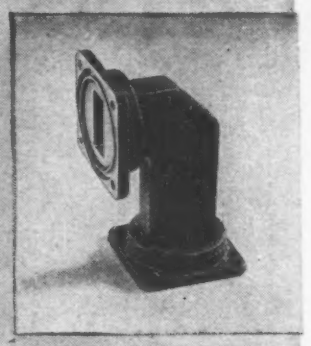


Rotating Joint DB-446

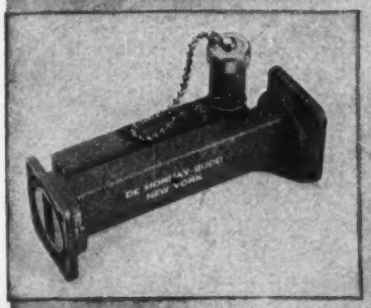
90° Elbow (H Plane) DB-433



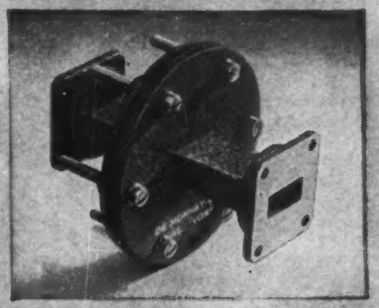
Pressurizing Unit DB-452



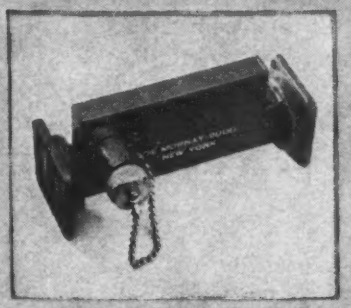
Mitered Elbow (H Plane) DB-439



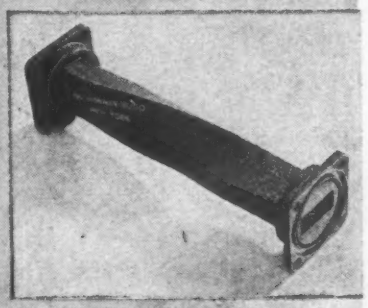
Uni-directional Broad Band Coupler DB-442



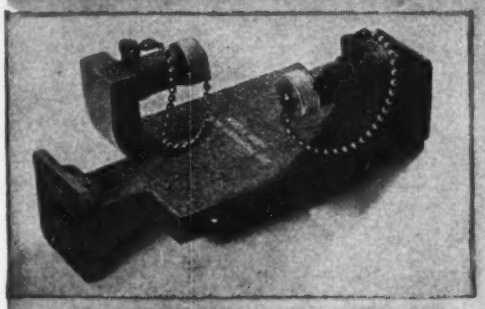
Bulkhead Flange DB-451



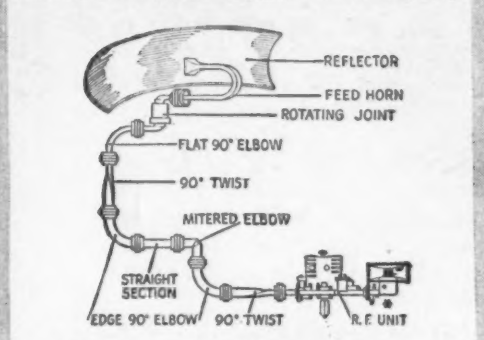
Uni-directional Narrow Band Coupler DB-440



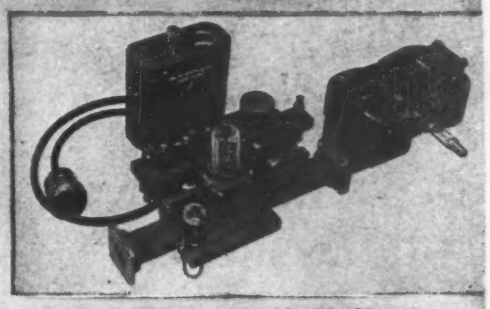
90° Twist DB-435



Bi-directional Narrow Band Coupler DB-441



Typical wave guide assembly illustrating use of De Mornay - Budd components available from standard stocks.



RF Radar Assembly DB-412

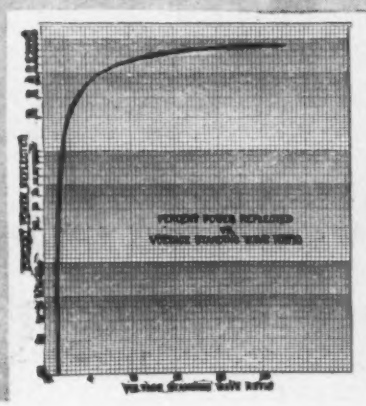
When you use any De Mornay·Budd wave guide assembly, you know exactly how each component will function electrically. You avoid possible losses in operating efficiency through impedance mismatches, or breakdown and arcing caused by a high standing wave ratio. (See chart below.)

De Mornay·Budd wave guides are manufactured from special precision tubing, and to the most stringent mechanical specifications. Rigid inspection and quality control insure optimum performance

NOTE: Write for complete catalog of De Mornay·Budd Standard Components and Standard Bench Test Equipment. Be sure to have a copy in your reference files. Write for it today.

The curve shows the manner in which the reflected power increases with an increase in the voltage standing wave ratio. The curve is calculated from the following equation:

$$\% \text{ Power Reflected} = \left(\frac{\left(\frac{V_{max}}{V_{min}}\right) - 1}{\left(\frac{V_{max}}{V_{min}}\right) + 1} \right)^2$$



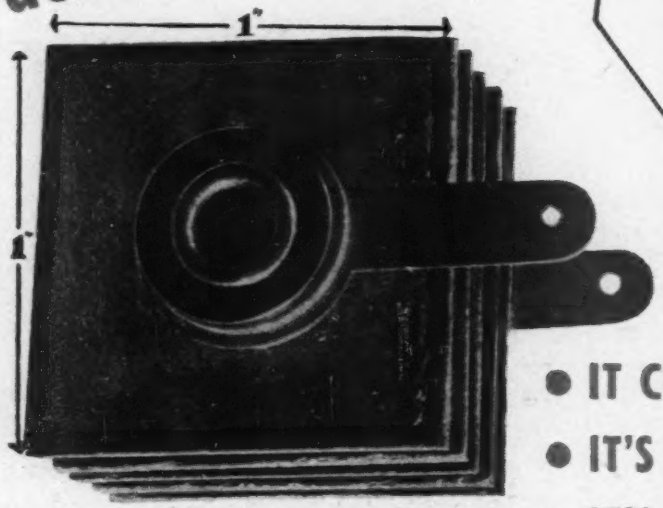
DE MORNAY BUDD

EQUIPMENT FOR 97% OF ALL RADAR SETS

De Mornay-Budd, Inc., 475 Grand Concourse, New York 51, N. Y.

don't use rectifier tubes . . .

USE THIS



- IT COSTS LESS
- IT'S SMALLER
- IT'S LABOR-SAVING

NEW Seletron* 5M1 MINIATURE

SELENIUM RECTIFIER

ONE STUD, two quick soldered connections and it's in! Usually costs less than the tube and socket it replaces. Compact—less than 1 cubic inch! Instant starting, cooler operation and longer life.

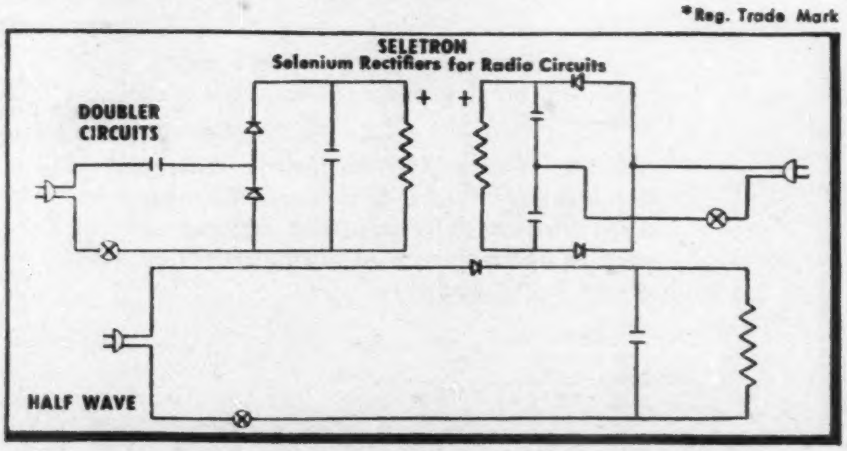
Radio Receptor, famous for Seletron built-on-aluminum selenium rectifiers now offers this MINIATURE unit to replace rectifier tubes in radio sets, amplifiers and other electronic devices.

Clicks with radio users because it has no fragile parts . . . eliminates rectifier tube replacements . . . helps batteries last longer.

Submit your problems. Write for details.

*Reg. Trade Mark

SELETRON
Selenium Rectifiers for Radio Circuits



Radio Receptor Co., Inc., Dept. S-6
251 West 19th St., New York 11, N.Y.
Rush me facts on new miniature Seletron Rectifier.
Name_____ Title_____
Company_____
Address_____
City_____ Zone___ State___

SELETRON DIVISION
RADIO RECEPTOR CO., Inc.
Since 1922 in Radio and Electronics
251 W. 19th St. • New York 11, N.Y.
Export Representatives:
Rocke International, New York

stalling the new ground system, new antenna and shifting of the existing antenna, the transmitter on 1,240 kc continued daily operation without interruption.

Precise measurements were made of the self and mutual impedances of the new array and from these measurements the operating impedances were calculated. Impedances of the various units and tower lighting transformers were measured and included in the calculations and the network component values were set up. Three conditions had to be satisfied simultaneously for the directional pattern; proper matching to coaxial lines, correct current ratio between the towers and the desired elec-

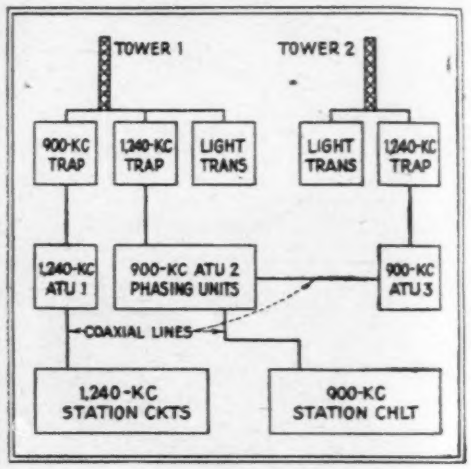


Fig. 1—Two transmitters on different frequencies feed one antenna system

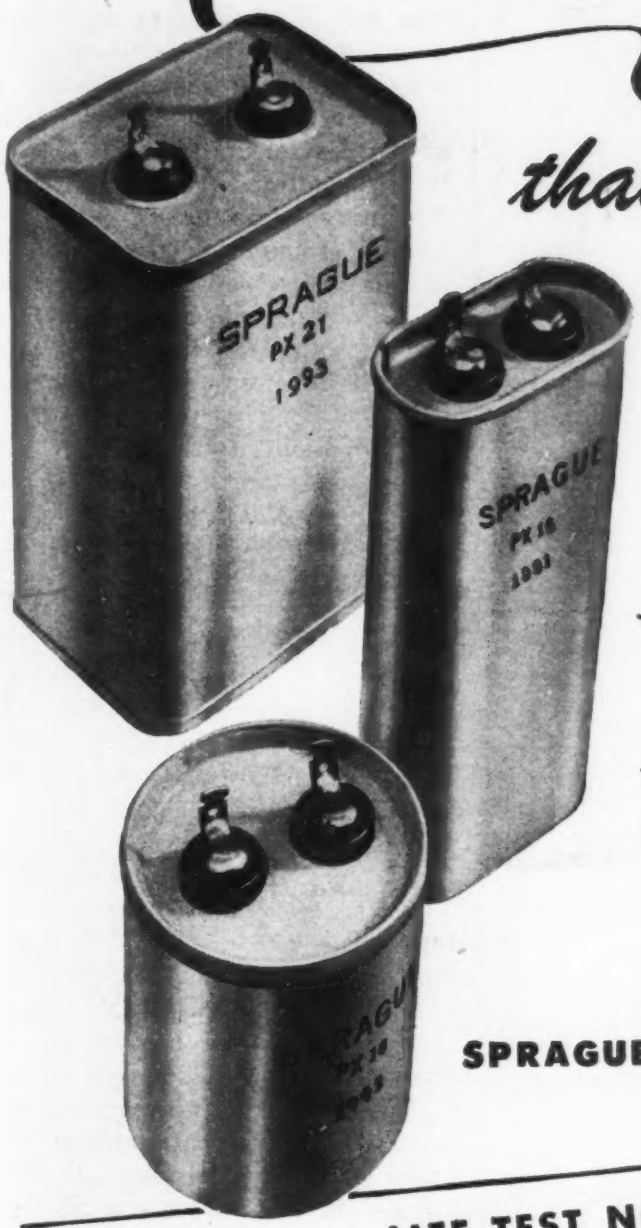
trical separation between the currents. Any one improper condition would throw the others out.

For instance, the self impedance of tower 2 changed radically when the phase difference between towers changed and if the phase difference were not correct the current ratio could not be obtained and the coaxial lines would also be mismatched. Only by precise measurements and careful setting up of the tuning unit components by r-f bridge method could the system be properly adjusted. The final arrangement of the various units is shown in Fig. 1.

Circuit Arrangement

Tower 1 is used during the daytime for both transmitters. CKTS. the 1,240-kc, 250-watt station is fed to this tower through a coaxial gas-filled line, a 1,240-kc antenna tuning unit (ATU1 in diagram) and.

INFINITELY LONGER LIFE FOR FLUORESCENT LAMP CAPACITORS...



thanks to SPRAGUE VITAMIN Q

(REG. U. S. PAT. OFF.)

Greatly increased production facilities now permit the application of Sprague's famous Vitamin Q impregnant to ballast capacitors for fluorescent lamps—with truly outstanding results. The tables below tell the story—on severe tests that leave nothing open to question as to the remarkable superiority of these Sprague units. *NO Sprague Vitamin Q Capacitors failed during the life of the tests. ALL of the competing units did!*

SPRAGUE ELECTRIC COMPANY, North Adams, Mass.

LIFE TEST NO. 1

Tested at 490v. A.C. 85°C. in circulating air

No. Units Tested	Maker	Hours Life at Failure of each unit tested 1st	2nd	3rd	4th	5th	Impregnant
5	SPRAGUE	NO FAILURES AFTER 750 HOURS !					VITAMIN Q
5	Mfr. 1	37	124	339	498	516	Chlorinated diphenyl
2	Mfr. 2	107	243	—	—	—	Mineral Oil

POWER FACTOR

550 v. A.C. 85°C.
(as measured on a Schering bridge)

Sprague	0.27%
Mfr. 1	0.62%
Mfr. 2	0.45%

Units tested in both cases were standard 3½ mfd. 330v. A.C. Fluorescent Capacitors in 2" d. x 2¼" h. cans.

LIFE TEST NO. 2

Tested at 575v. A.C. 85°C. in still air

No. Units Tested	Maker	Results	Impregnant
4	SPRAGUE	NO FAILURES AFTER 750 HOURS !	VITAMIN Q
3	Mfr. 1	All failed in less than 4 hours	Chlorinated diphenyl
3	Mfr. 2	" " " " " 4 "	Mineral Oil
3	Mfr. 3	" " " " " 4 "	Mineral Oil

Type AN3102 Receptacle Shells, sizes 8S to 48

AN3108 Plug

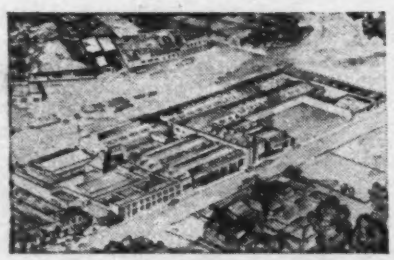
AN3106 Plug

AN3100 Recep.

AN3101 Recep.

Developed prior to World War II for standardization purposes, the AN (Army-Navy Specifications) Connector type series remains as one of the most versatile and widely known lines of electric multi-contact fittings. The large range of shell sizes, insert arrangements, interchangeable parts and accessory fittings make the Cannon Electric "AN" a desirable, all-purpose connector. Cannon Electric's "Quality Control" from diecasting to assembled fitting produces a dependable product used extensively not only in aircraft but also in radio, radar, instruments and countless general electrical applications.

Thousands of aircraft and radio technicians worked with these *"Cannon Plugs"* during the war; the same thousands are still demanding Cannon quality in peacetime because they know it served them well when the perfect operation of every electrical part of the war machine meant the protection of lives and more efficient prosecution of the offensives.



The 6th Revised Edition of the "AN" Bulletin will be mailed free upon request. Write Dept. K-120, Cannon Electric Development Co., 3209 Humboldt Street, Los Angeles 31, Calif. Prices on specific "AN" Connectors must be obtained from Cannon representatives located in principal cities or directly from factory. For those living outside the U. S. A. and in countries other than the British Empire, write Frazar & Hansen, 301 Clay Street, San Francisco 11, Calif.

CANNON ELECTRIC

DEVELOPMENT COMPANY

3209 Humboldt St., Los Angeles 31, Calif.

IN CANADA (and British Empire export)
CANNON ELECTRIC COMPANY, Ltd., TORONTO

SINCE 1915

a rejector unit. The rejector unit is resonated at 900 kc to prevent feedback into the 1,240-kc line from the 900-kc circuit. CHLT, the 900-kc, 1,000-watt station, is fed to the same tower by a coaxial gas-filled line, a 900-kc antenna tuning unit (ATU2), and a rejector unit which is resonated at 1,240 kc to prevent this frequency from feeding back into the 900-kc circuit. Tower 2 also has a 1,240-kc rejector unit and the tower is detuned during the daytime to prevent radiation.

At sunset, a changeover is made at the control unit on the desk at the transmitter building and tower 2 is brought into the 900-kc circuit. This is accomplished by two relays at Tower 1 which change taps on ATU2, disconnect the detuning circuit of tower 2, and also put this tower in the circuit through a phasing unit. The phasing unit matches this junction to the coaxial line running to tower 2, where antenna tuning unit ATU3 matches the line to the tower through the 1,240-kc rejector unit.

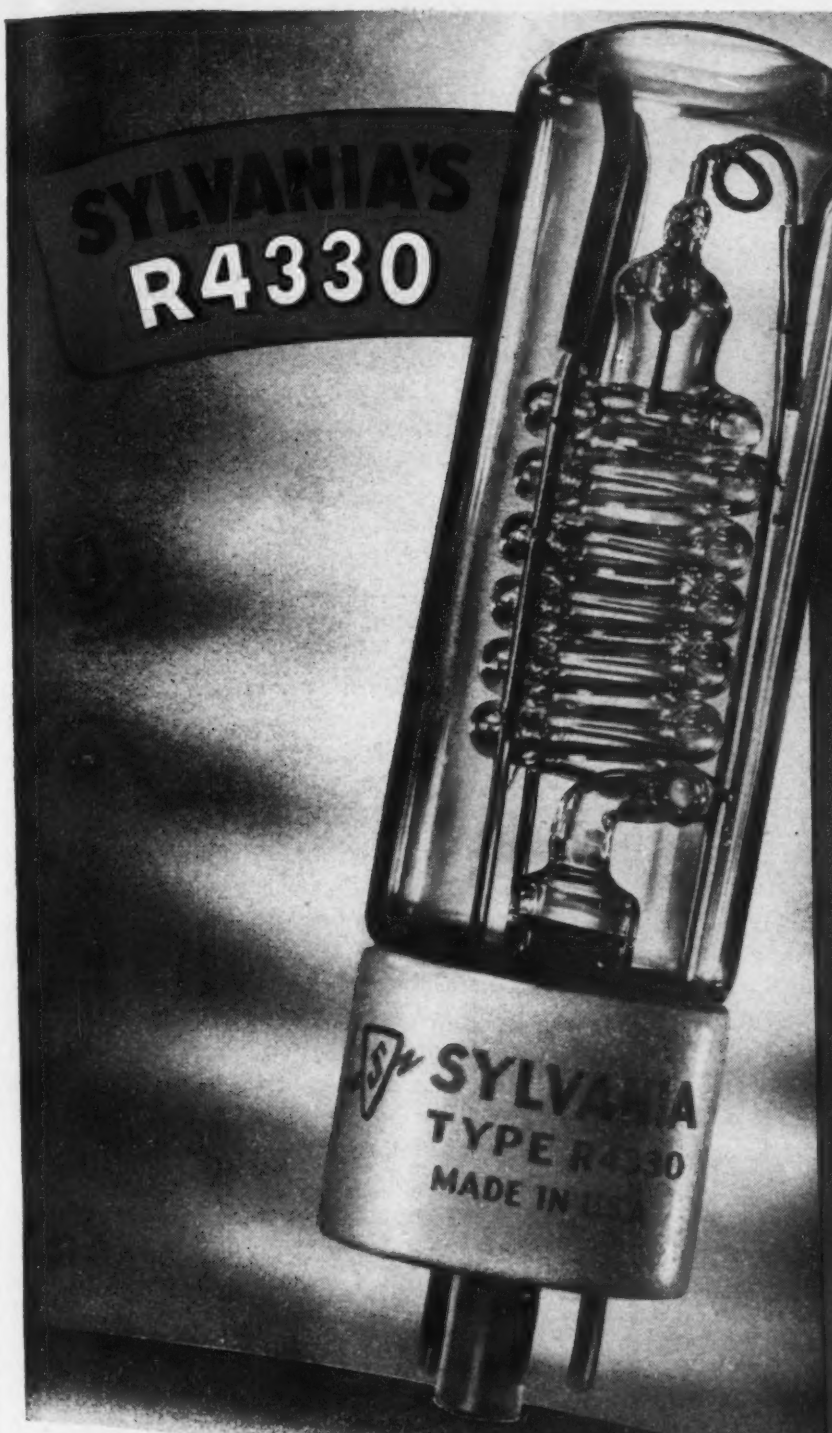
Power Division

In the 900-kc circuit at tower 1, phase changes through the antenna tuning and phasing units cancel each other. The 120-degree coaxial line between towers causes a phase shift of −130 degrees and ATU3 is tuned to shift the phase another −89 degrees. This provides the total of −219 or +141 degrees phase difference required.

The setting of the 1.3 to 1 current ratio between the towers is accomplished at the junction of ATU2 and the phasing unit at tower 1. From the calculated directional operating resistances of the towers, the power required in each tower for correct current was found. The necessary power division to produce these currents is made at the junction by matching ATU2 to tower 1 and the phasing unit to the inter-tower coaxial line so that their parallel input impedances correctly divide the power and also match the surge impedance of the coaxial line to the transmitter.

Operation

In changing from one-tower omnidirectional operation to two-tower directional, the shift is made



NEW ELECTRONIC TUBE FLASHES THOUSANDS OF TIMES

WITH BRILLIANT INTENSITY

The Sylvania Type R4330 Flash Tube, used with suitable equipment, gives a brilliant flash of excellent photographic quality with a duration of only 1/5000th second.

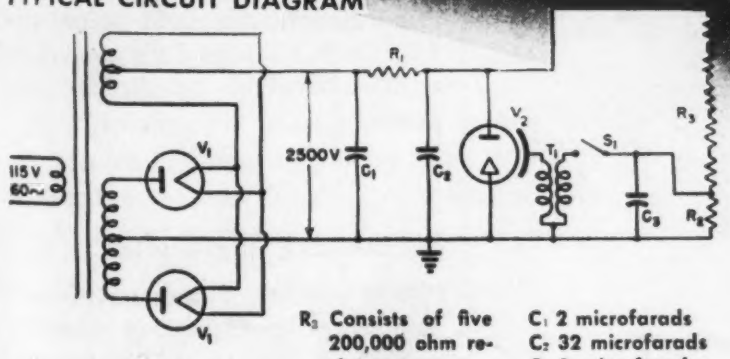
A major application of the Type R4330 is in newly developed electronic flash units for photographic purposes. Here it permits taking pictures without the need for replacing flash bulbs. Its short flash duration "stops" motion, enabling the photographer to take sharp, clear pictures of moving subjects. Excellent color quality permits use with color film.

Each time the circuit switch is closed, the tube emits a single flash. The tube has a life of several thousand flashes.

Other uses of the R4330 are in beacons, obstruction markers, airport boundary markers and signaling devices. *See your Sylvania Distributor.*

Wabash Portable AC Electronic Unit — one of the pieces of equipment utilizing Sylvania's electronic flash tube R4330.

TYPICAL CIRCUIT DIAGRAM



R_1 500 ohms, 100 watts
R_2 150,000 ohms
R_3 Consists of five 200,000 ohm resistors
V_1 High voltage rectifier
V_2 Sylvania R4330
C_1 2 microfarads
C_2 32 microfarads
C_3 1 microfarad
T_1 Ignition coil
S_1 Trip switch

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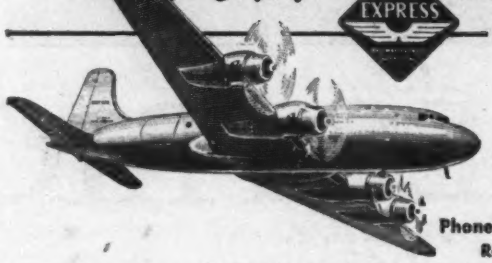

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at sunset in approximately one second during a station break for identification. The tuning units at the towers are so adjusted that the coaxial line impedances at the transmitter for the two modes of operation are identical and no transmitter adjustment or retuning is necessary.

As a visual check on the shape of the night pattern, two field indicators have been installed. These consist of small receivers, containing a diode rectifier and d-c amplifier, set up in the field about 400 feet from the towers, one on each side of a low signal zone. The units are mounted on posts and are powered by a 110-volt a-c line. The output of each unit is taken by cable to d-c microammeters in the control unit on the desk at the transmitter building. Changes in the reading of the meters outside of a predetermined operating tolerance indicate to the operator that the pattern shape has altered. Cables also carry the antenna currents to remote meters in the desk control unit and provide a constant check on the currents in the towers for both transmitters.

To uncover any signs of interaction between the two stations, various tests were carried out. It was found that any switching on or off of one transmitter in no way affected the meter readings or field intensity of the other. Either carrier, fully modulated, did not affect the unmodulated carrier of the other transmitter and no signs of cross modulation could be detected with both stations fully modulated with individual or similar programs.

Microwave Wattmeter

POWER OUTPUT of transmitters and oscillators operating at frequencies from 20 to 1,500 mc and 50-ohm coaxial output terminals is measured by a wattmeter whose wide-band impedance constancy is realized by employing a length of attenuating 50-ohm coaxial cable terminated in a resistor. The basic idea is that the resistor determines the impedance at the lower frequencies and the line determines it

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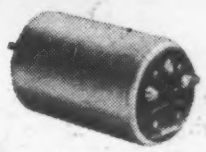
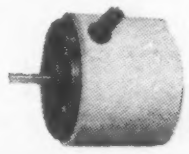
A FEW TYPICAL 400 CYCLE MOTORS . . .

1. **Model J33**
115 volts, 400 cycles, 8000 R.P.M. Synchronous, 3-phase.

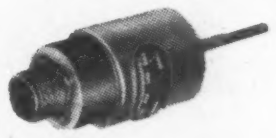


2. **Model J31A**
115 volts, 400 cycles, 1/100 H.P., 7200 R.P.M. 1-phase.

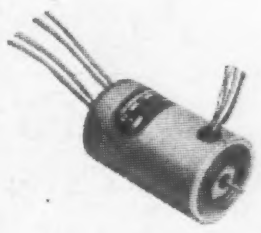
3. **Model J72**
115 volts, 400 cycles, 1/15 H.P., 5500 R.P.M. 1-phase.



4. **Model M6B**
200 volts, 400 cycles, 3-phase, High torque actuator motor. Total weight 12 oz.



5. **Model J37**
115 volts, 400 cycles, Motor-generator set. 2-phase servo-motor drives induction generator. 400 cycle output voltage varies with frequency. Used for anticipatory control of electronic servo system.



Single shaft passes through and locks with rotor of each unit.

Each unit can be wound to precise circuit requirements, as to resistance, taper, tap, hop-off.

Interlocking resistance ratios provide any desired voltage or current at given degree of rotation.

Note dual unit with screw - driver adjustment. Such assemblies are serving in the most intricate electronic assemblies.

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★ **For three or more controls in tandem, Clarostat Type 42 is the logical choice. The bakelite cases of these rheostats or potentiometers nest and lock together for a virtually solid casing. Metal end plates and tie rods insure a rigid assembly—even up to 20 units in tandem. This unit is the solution to your multiple - circuit control. Back - lash is completely eliminated. And it is typical of that Clarostat "know-how" which provides the answers to all your resistor, control or resistance-device problems.**

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at the higher frequencies, with a smooth transition. Distribution of power loss changes in the same manner in the instrument made by Bird Electronic Corporation of Cleveland.

In all attenuating coaxial cables so far made, the attenuation increases with frequency. A length of such attenuating line furnishes a constant input resistance equal to its characteristic impedance, regardless of termination of the line, for frequencies sufficiently high so that the reflections produced by an imperfect termination can be neglected.

Constant Resistance

In general, the constant resistance termination over a wide frequency range is obtained in the Bird wattmeter by using the Z_o of the attenuating lines at the higher frequencies. In order that low frequencies may be handled with a reasonable cable length, the line is terminated in a specially designed coaxial resistor.

As the attenuation of the line increases with frequency, a "transfer of power loss" occurs gradually from the 20-mc condition, in which about 25 percent of input power is dissipated in the terminating resistor, to the 1,000-mc condition, in which 90 percent of the input power is lost in the initial 25 feet of line. The frequency 200 mc may be stated roughly as the upper limit of effects from the terminating resistor and at higher frequencies the line alone determines input resistance.

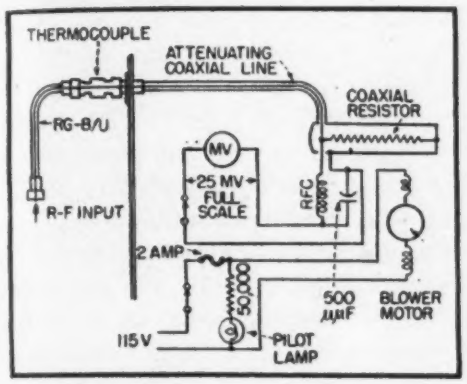
The wattmeter uses one hundred feet of a synthetic rubber dielectric, copper-conductor type of line. The average characteristic impedance of this line is 47 ohms and this fixes the load resistance presented to a thermocouple. The calibration of the individual wattmeter is made so as to include the effects of variation of individual lengths of line from the 47 ohm nominal value.

Measuring Equipment

The coaxial termination is blower cooled and rated 500 watts. A d-c millivolt-meter is used as the power indicator.

Plug-in thermocouples are provided to cover desired portions of the power range from 1 to 500 watts. The thermo junctions of the

thermocouples form a short portion of the center conductor of the coaxial line, are heated by the r-f current therein and generate, in series with the center conductor, a d-c voltage proportional to r-f power level. The thermocouple d-c output is proportional to current squared and hence to power, but convenience dictates direct calibration in terms of power.



Complete circuit of the wattmeter for use from 20 to 1,500 megacycles

The wattmeter may be used to measure the power output on transmitters designed for 72-ohm loads. It is preferable to use 50-ohm cables and connectors between wattmeter and transmitter, in the case of 72-ohm transmitters also. The idea here is that the standing wave ratios existing on the cables are determined by the wattmeter impedance and the Z_o of the cables, and are independent of the transmitter. With 50-ohm cables, the impedance presented to the transmitter terminals will depend very little on cable length.

New Station Techniques

AS A RESULT OF conditions forced upon it by the war, the British Broadcasting Corporation has developed new conceptions of studio organization which it intends to retain.

Before 1939 the broad tendency was to use a number of simple studios for different classes of programs or scenes in a dramatic production and to centralize in a single control room all technical equipment. Now, however, this has been superseded by general purpose studios, each having its own technical

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TURNER COLORTONE CRYSTAL
- Highest quality Metalseal, moisture proofed crystal.
- 90° tilting head. Semi or non-directional operation.
- Wind and blast proofed.
- Barometric compensator.
- Choice of color finishes.
- Turner precision diaphragm.
- 20 ft. removable cable set.
- Response: Within ± 5db from 50 cycles to 10,000 cycles.
- Level: -52db below one volt/dyne/sq.cm.

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TURNER COLORTONE DYNAMIC
- Heavy duty dynamic cartridge.
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equipment consisting of a control desk and an apparatus cabinet.

Among the technical points changed is the abandoning of mixing of microphone circuits at microphone level. This was done because the high-quality microphones in universal use today are relatively insensitive. When several are mixed, the level is low enough to demand series faders and so the signal level varies according to the number of circuits faded up at one time. Furthermore, the necessary equalizer circuits still further depress the level until it is very near the Johnson noise background and other extraneous noises. The modern practice now is to give each microphone its own amplifier and then to mix after amplification.

Group faders are used as well as individual faders and this facility allows the program engineer to fade out any given combination of microphone channels in one movement, to fade up a single microphone for an announcement, and then to revert to the original arrangement immediately.

Echo Room

All microphone channels are passed through splitting transformers so that some of the program can be passed into an "echo" room and then reintroduced into the "direct" half of the outgoing circuit. Suitable attenuators are introduced and thus a radio play may use several microphones in one studio (as is now common) for various scenes, yet individual outputs can be adjusted for varying degrees of echo.

The program output of a studio is monitored by a program meter and loudspeakers and phones.

The various auxiliary circuits include remote switching of spare amplifiers, loudspeakers in studios for playback apparatus for introducing line-up tone, all interlocked with the microphone circuits to prevent the wrong material being radiated or howling set up.

The control desks associated with each studio are made for use by two persons, a program engineer and a producer. The controls, which are on the inclined face of the desk, are divided among three panels. These panels are arranged to swing forward for maintenance

A deservedly popular 50 watter

The Collins 32RA* was introduced several years ago as a quality designed, quality built radio communication transmitter, broadly adapted to most applications within its power and frequency scope.

It and the d-c version, the 32RB†, were immediately put into service by airlines for control towers, by oil pipelines for emergency systems, by fishing companies for fleet control, and by other widely different types of industrial users.

The 32RA was found to be rugged, simple to operate, easy to service, and so thoroughly and universally satisfactory that a rising commercial demand was halted only by the war.

Now it is again available for peacetime applications. A large number of orders have already been received and filled, and we are able to ship from stock. If you would like specifications and design data, write us for an illustrated descriptive bulletin.

*COLLINS 32RA—Power source: 115 volts alternating current. Power output, 50 watts phone; 75 watts CW. Frequency range, 1.5 to 15 mc. Four frequencies instantly selected by panel control.

†COLLINS 32RB—Power source: 12, 24, 32 or 110 volts direct current. Dynamotor, self-contained. Otherwise identical with 32RA.

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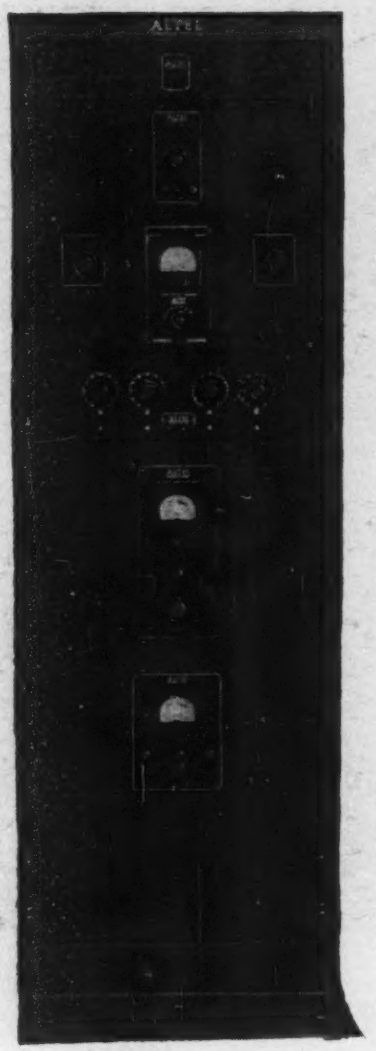

This complete recording amplifier channel develops full power from 40 to 10,000 cycles without the usual dirty highs or intermodulation distortion. No other amplifier system can produce such performance. Another Altec Lansing first . . . it is ideal for studio recording. Available complete or in separate units.

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and are quickly demountable. The division of the controls on the panels has been done on a functional basis; thus, the central panel carries all the important controls and is operated by the program engi-

A program engineer and a producer at a new B.B.C. control console. The panel at the right is for use by the producer, the center and left-hand panels contain more technical controls

neer, while the right-hand panel carries such controls as the "talk-back" key and others which the producer might want to use. The left-hand panel carries purely technical controls associated with switching on the equipment, echo mixture, and keys operating relays controlling spare amplifiers. The circuits of the last mentioned have been designed with extreme care and it is virtually impossible to detect that an amplifier has been replaced.

Frequency Modulation

In this regard, the British Broadcasting Corporation has for some time been interested in frequency modulation and has now summarized the results of extensive field trials. On the whole, the engineering executives appear to be pleased with f-m but they are by no means accepting it as perfect. There are so many dependent factors. For example, the actual noise level at the receiver depends, among other things, on any motor vehicles passing the premises being fitted with efficient interference suppressors. Again, the f-m system offers an increased range of modulation but this advantage is cancelled if the receiver does not have sufficient a-f power-handling capacity to utilize the benefit. Similarly, it is

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INSULATED WITH Du Pont POLYTHENE

With the home television set, much of the attenuation and distortion of images that sometimes occurs on the screen may arise in the lead-in cable from the antenna to the instrument. But not with the new Type ATV cable shown here. With this cable, attenuation is minimized . . . images are strong and clear.

The unusual design of this new lead-in line deserves much credit for its high effectiveness. But note—what makes this design possible is the excellent electrical properties of the insulation, of Du Pont polythene.

Because of polythene's remarkable dielectric strength, a thin coating of it is all that is needed. Polythene's low power factor makes it unusually effective in every type of high-frequency circuit. Credit also polythene's light weight (specific gravity 0.92) and its ability to retain its toughness and flexibility over a wide range of temperatures.

For complete data sheet on polythene, write to E. I. du Pont de Nemours & Co. (Inc.), Plastics Dept. 1511, Arlington, N. J.

Du Pont manufactures polythene molding powder.
Commercial extruders convert polythene into the form of

Type ATV two-wire polythene-insulated cable, for use as television lead-in line between antenna and receiver, made by Anaconda Wire & Cable Co. (Photo 2.5 times actual size.) This rugged, flexible cable, one of the lightest of its type, has an attenuation of 0.75 db/100 feet, and an impedance of 300 ohms at 50 megacycles.

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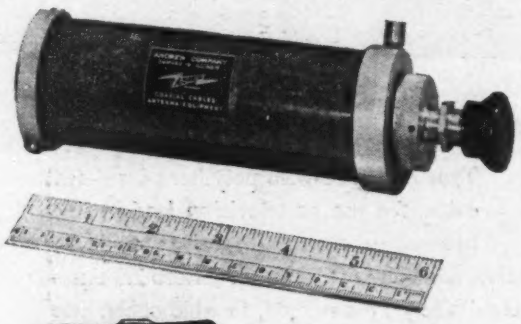
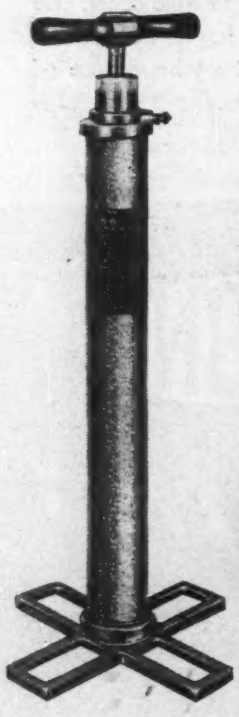
TYPE 1800
AUTOMATIC DEHYDRATOR

A compact, *completely automatic* unit that pressurizes coaxial transmission lines with clean, dry air. Starts and stops itself. Maintains steady pressure of 15 pounds. A motor driven air compressor feeds air through one of two cylinders containing a chemical drying agent where it gives up all moisture and emerges absolutely clean and dry. Weighs 40 pounds; 14 inches wide, 14 inches high, 11 inches deep. Power consumption, 210 watts, 320 watts during reactivation.



TYPE 720
PANEL MOUNTING
DRY AIR PUMP

Specially designed for use in equipment requiring a small, built-in source of dry air. Only 2 inches in diameter, 6 inches long. Pressures as high as 30 pounds are easily generated. Piston type compressor drives air through a chemical drier. Pump supplies dry air with only 7 to 10% relative humidity. Additional silica gel refills available at reasonable cost.



TYPE 876-B

Designed over the simple tire pump principle, this all-purpose dry air pump has numerous applications. Output of each stroke is about 26 cubic inches of free air. Transparent lucite barrel holds silica gel. Supplied complete with 7-foot length of hose. Height 25½ inches. Net weight 8½ pounds.

Andrew Dry Air Equipment is used in a multitude of other applications. Write for further information.

ANDREW

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363 E. 75th ST., CHICAGO 19, ILLINOIS
Pioneer Specialists in the Manufacture of a Complete Line of Antenna Equipment

well known that f-m offers the possibility of really high fidelity but what is this worth if the loudspeaker designer ignores what the transmitter engineer can give him?

The question of preemphasis at the transmitter and deemphasis at the receiver has been examined very carefully by the B.B.C. and the judgment is that a preemphasis of 50 μsec would be best for use. But here too the whole matter is tied up with loudspeaker design. Preemphasis, incidentally, is defined as the time constant of a circuit having the required frequency characteristic.

Interference Ratio

Concerning the matter of mutual interference between stations having a common service area, it was found in trials that 10 db(3:1) between two stations gave no intelligible intereference. There was just a rasping sound. But to make a substantial reduction in this, 20 db(10:1) was the figure required and to eliminate completely all mutual interference a 30 db(30:1) difference was wanted.

The tests, however, brought out the immense superiority of f-m in this respect since 30 db gives complete freedom from interference whereas with a-m even 46 db(200:1) does not produce the condition of no interference.

The frequency deviation of an f-m transmitter is judged to be adequate at ± 75 kc and once again dependent factors arise since a narrow deviation band demands receivers with very stable oscillators although it has the advantage of permitting more channels in a given ether space. The amount of deviation is also tied up with the "capture" effect.

The field trials discussed above not only included measurements but a number of tests by ear. From these last tests a certain amount of disappointment emerged—f-m did not seem to some people to produce the expected background of silence.

Alternatives to f-m and a-m have also been tested by the B.B.C. and it has been found that f-m is definitely superior to pulse modulation systems for high fidelity working and high fidelity has always been

Your Cable Problems

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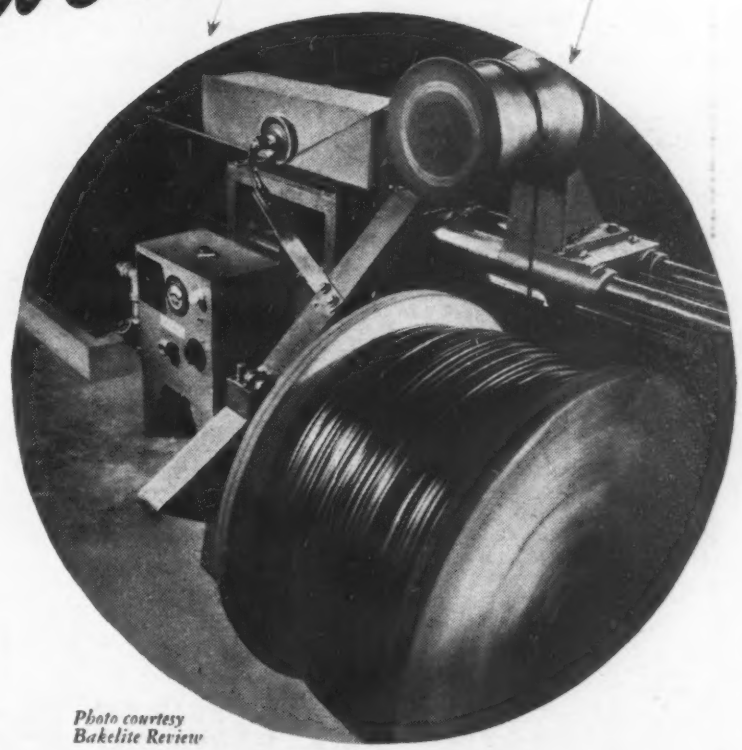

We have designed many cables which have solved a multitude of problems. When you come to Ansonia for something original in cables, our engineers will turn out a product to meet your specific requirements.

Photo courtesy Bakelite Review

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a main consideration with the Corporation, which strives to keep its transmitters ahead of receivers.

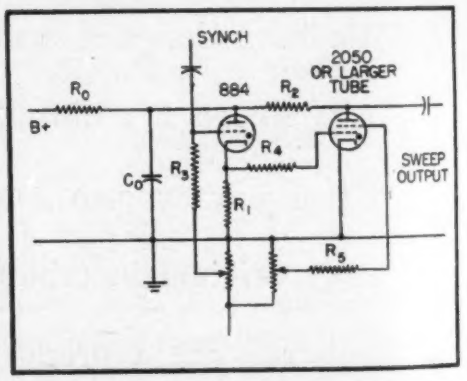
Both these summaries of recent B.B.C. technical work have been made with the permission of the Corporation and fuller details are contained in its new journal, *B.B.C. Quarterly*. —J.H.J.

Speeding up the Return Trace

BY A. H. TAYLOR

IN THE CONVENTIONAL sawtooth sweep circuit used in cathode-ray oscilloscopes, the speed of the return trace is limited by the permissible peak current of the gas tube.

Usually the gas tube is fired at 50 volts or less when charging from several hundred volts, to use only the initial, nearly linear part of the exponential voltage curve. The type 884 thyratron is particularly suitable for this because of its linear control characteristic, extending even to low plate voltages. Unfortunately, its permissible peak plate current is but 300 ma. Type 2050, on the contrary, will handle a peak of one ampere but has at low plate voltages an excessively curved control characteristic that makes for unsteady operation.



Sawtooth oscillator circuit combining advantages of 884 and 2050 to obtain rapid return trace of beam in c-r tube

The circuit shown combines the good triggering characteristic of the 884 with the high peak current of the 2050. Other types might be used. Resistor R_1 limits instantaneous peak current through the 884 and supplies a tripping pulse to the 2050; R_2 limits instantaneous peak current through the 2050; R_3, R_4, R_5 limit the grid currents. The combination of R_0C_0 is the sweep circuit.

MORE THAN 16,000,000 MOLDED OF G-E MYCALEX

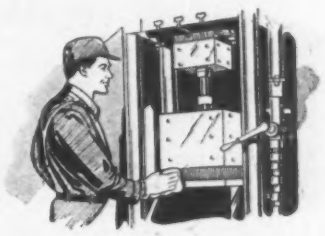
●Here is an example of precision molding a critical component in G-E mycalex and supplying it by the million. The aircraft engine spark plug terminal sleeve had the advantage of being "self-healing" after exposure to prolonged arcing. It lent itself to ground crew maintenance of our warplanes.

This is but one of the many parts molded in G-E mycalex by General Electric during the war. Why not consult G-E engineers, who have perfected G-E mycalex molding techniques, about your insulation problems? You may heighten the efficiency of your product *and save on over-all insulation costs* by using a G-E mycalex precision molded part.

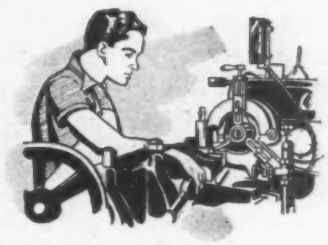
G-E mycalex, a stone-hard, gray-colored material that is produced by fusing special glass with powdered mica, is now available to you in standard rods and sheets . . . fabricated parts . . . or molded to your own design. A new bulletin tells the whole story of unique G-E mycalex—send for it today. Plastics Divisions, S-15, Chemical Department, General Electric Company, 1 Plastics Avenue, Pittsfield, Massachusetts.

HOW THE G-E MYCALEX SERVICES CAN BENEFIT YOU NOW

You may order fabrication of sample G-E mycalex parts at surprisingly low cost. Test them yourself in your own equipment. Then, if you decide to specify G-E mycalex, your design can be converted to a molding process which permits speedy and economical production runs.



MOLDING SERVICE



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Get This Unique Combination of Properties with G-E Mycalex

1. High dielectric strength
2. Low power factor
3. Prolonged resistance to electrical arcs
4. Chemical stability—no deterioration with age
5. Dimensional stability—freedom from warpage and shrinkage
6. Impervious to water, oil, and gas
7. Resistance to sudden temperature changes
8. Low coefficient of thermal expansion
9. High heat resistance

Samples Supplied on Request

GE MYCALEX

GENERAL ELECTRIC

CD46-M18

INDUSTRIAL CONTROL

Edited by VIN ZELUFF

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Radarange for Cooking 178
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High-Speed Counter 190
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Testing Automobile Engines

AT THE DODGE automobile main plant, electronically controlled dynamometer test stands provide a new automatic means of testing and adjusting car engines. A novelty of the setup is that each engine drives a generator that feeds electric current into the plant's power line. In one hour, 510 kilowatts are generated by the engines on test.

The dynamometer test stands take the place of the old block test which required an hour and a half, and the old dynamometer test, which took an additional ten minutes, not counting time to transfer the engines between stands. The time required for fully testing an engine has been reduced to 20 minutes. A saving is accomplished also by eliminating the bank of engines manufactured ahead of assembly line needs to offset the uncertainty of the former method of engine testing.

The engine conveyor delivers finished engines directly to the new dynamometer room where sixty dynamometer test stands are arranged in two rows alongside the conveyor line of moving engines. Virgin engines are lifted by overhead cranes directly from the line to the dynamometer stands.

Test Cycle

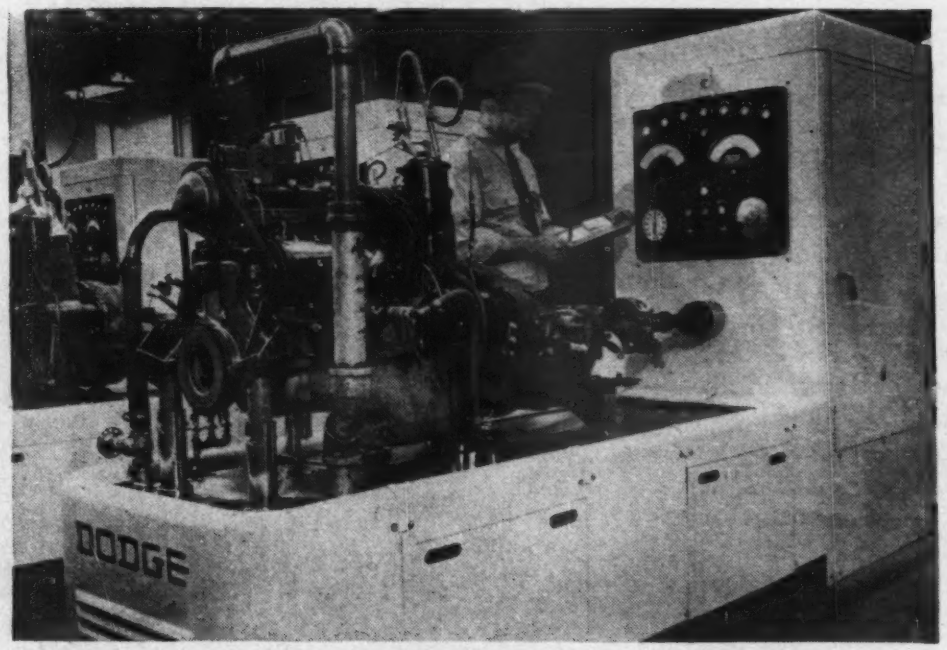
One of the test stands is shown in the illustration. The upright cabinet contains a generator and electronic controls that operate an instrument panel. Adjoining it is the base on which the engine is mounted. Fuel, water, oil, and exhaust-gas lines are concealed underground. A hydraulically operated throttle adjusts automatically as the engine runs from idling speed up to full load. Practically no human error can enter into the testing procedure.

The engine operates for five minutes at an idling speed of 500 rpm, with filtered oil constantly flushing through the crankcase. Then the electronic controls apply a half load on the generator, the throttle opens up, and the engine runs for 12 minutes at half load. During the first seven minutes at half-load, oil continues to flush through the crankcase, while a filtering system takes out any metallic traces remaining from the manufacturing process. The oil drain is then closed automatically, the crankcase is filled to operating level, and the last five minutes of the half-load test is run with oil circulating within the crankcase.

The engine is stepped up to full load at 1250 rpm for the final three minutes of the test. During the run, the operator of the stand gives all connections and cylinder head studs a final tightening, and an inspector checks each engine for power output and every engineering specification.

On the dynamometer instrument panel, flashing lights show instantly that the oil pump, water pump, and thermostats are functioning, and that the ignition timing is correct. At the end of the 20-minute run the engine is shut off and oil and water are drained automatically. Five minutes later, the engine is back on the conveyor, on its way to be installed in a new Dodge.

The technique developed as an outgrowth of experience in testing more than 18,000 engines for B-29 Superfortresses at Chrysler Corporation's wartime-operated Dodge-Chicago plant.



Dynamic testing of Dodge automobile engines is being accomplished by sixty electronically controlled test stands. Above, an inspector checks meters showing rpm, horsepower developed, and 14 other indicators

Radarange for Cooking

MICROWAVE cooking using a magnetron and a horn antenna to direct r-f energy into food is the latest development in the field of electronic heating. Called the Radarange by Raytheon Manufacturing Co., the equipment bakes biscuits and gingerbread in 29 seconds, cooks hamburgers with onion in 35 seconds, and grills a frankfurter and roll in eight to ten seconds. A package of frozen food can be placed in the range, defrosted in a few seconds, and cooked in a few more seconds.

The equipment, shown in the pho-

FRANKLIN AIRLOOPS now covered by basic patent #2,401,472

FRANKLIN AIRLOOPS NOW COVERED BY BASIC PATENT

Patent No. 2,401,472 covering the new loop antenna, known as the AIRLOOP, has just been issued by the U. S. Patent Office. The claims issued are basic in scope as is evidenced in claim No. 1 which is typical and follows:

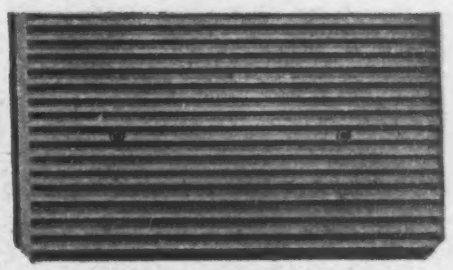
1—An air dielectric inductance comprising a panel of insulating material and a continuous metal strip formed from a metal sheet and attached to one face of said panel in the form of a spiral, the planar width of said strip being equal to the pitch of said spiral and said strip being in channel form to provide a free air space between adjacent turns of said spiral.

In addition to the above, other patents are pending, domestic and foreign, covering the methods of manufacture and items such as stamped electrostatic shields, stamped disc type commutators, stamped inductance coils, stamped wiring circuits and for the molding of loops and creative metal designs in cabinets which are of plastic or inert materials.

The Franklin Airloop Corp., which has the rights to the use of this patent, offers its experimental laboratories to assist in the development of any item which can be manufactured by the stamping method covered in these patents.

FRANKLIN AIRLOOP

SHORT WAVE INDUCTANCE COIL



ELECTROSTATIC SHIELD

DISC TYPE COMMUTATOR
MULTIPLE SWITCH
VARIABLE RESISTANCE

Illustrated are but a few of the items that can be manufactured by the method covered in this patent . . . many others are now in development . . . you, too, may conceive a use for this patented method and in such case the Franklin experimental laboratories will be glad to assist in its development.

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MOLDITE IRON CORES

Supplied to your exact specification!

STANDARD IRON CORES—National Moldite molded cores can be supplied for any size coil with or without inserts, if desirable. New formulae make higher Q values possible; and accurate powder control assures uniform density. Cores are currently produced in quantity for ultra high, high, medium and low frequencies. Modern facilities permit rigid adherance to critical mechanical and electrical specifications.

PERMEABILITY TUNING CORES—National Moldite is one of the largest producers of tuning cores in the country. This leadership and large scale production result in efficiency and economy that has proven important to customers. Any size run, with the most critical specifications, can be handled with exact uniformity of all pieces.

SPECIALIZATION

National Moldite iron cores are produced by specialists engaged exclusively in the manufacturing of iron cores. A complete line of magnetic iron cores for use at all frequencies including television and FM is now available.

ENGINEERING

It is a simple matter for National Moldite engineers to fit the right core to your particular coil for the best results. Thoroughly familiar with every iron core application, these technicians will be glad to assist you in determining which of these components can best meet requirements.

PRODUCTION

With vastly expanded production facilities, National Moldite is in a position to meet your immediate iron core requirements. Quality, economy and dependability are assured, without sacrificing assembly schedules or delivery deadlines.

SAMPLES

National Moldite sample iron cores will be submitted for design, test and pre-production purposes upon receipt of your request. Use Moldite material grade designations to insure prompt and exact duplication of the required cores. Specify "MOLDITE" for "QUALITY"

RMA RADIO MANUFACTURERS ASSOCIATION

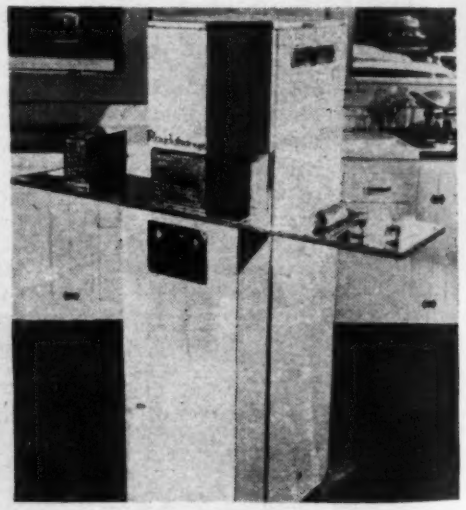
NATIONAL MOLDITE COMPANY

25 MONTGOMERY STREET — HILLSIDE, NEW JERSEY

graph, is so arranged that the magnetron and horn assembly are above

Food to be cooked in the Raytheon Radarange is placed in the ventilated "oven" and inserted in the cabinet where r-f is squirted into it from the horn antenna

the cooking area to practically beam the r-f output into the food being cooked. The only controls are two pushbuttons and a timer setting. In operation the timer is set for the desired cooking time and the button pressed. When cooking is completed, the timer automatically



The magnetron and horn assembly are mounted in the top of the Radarange cooker

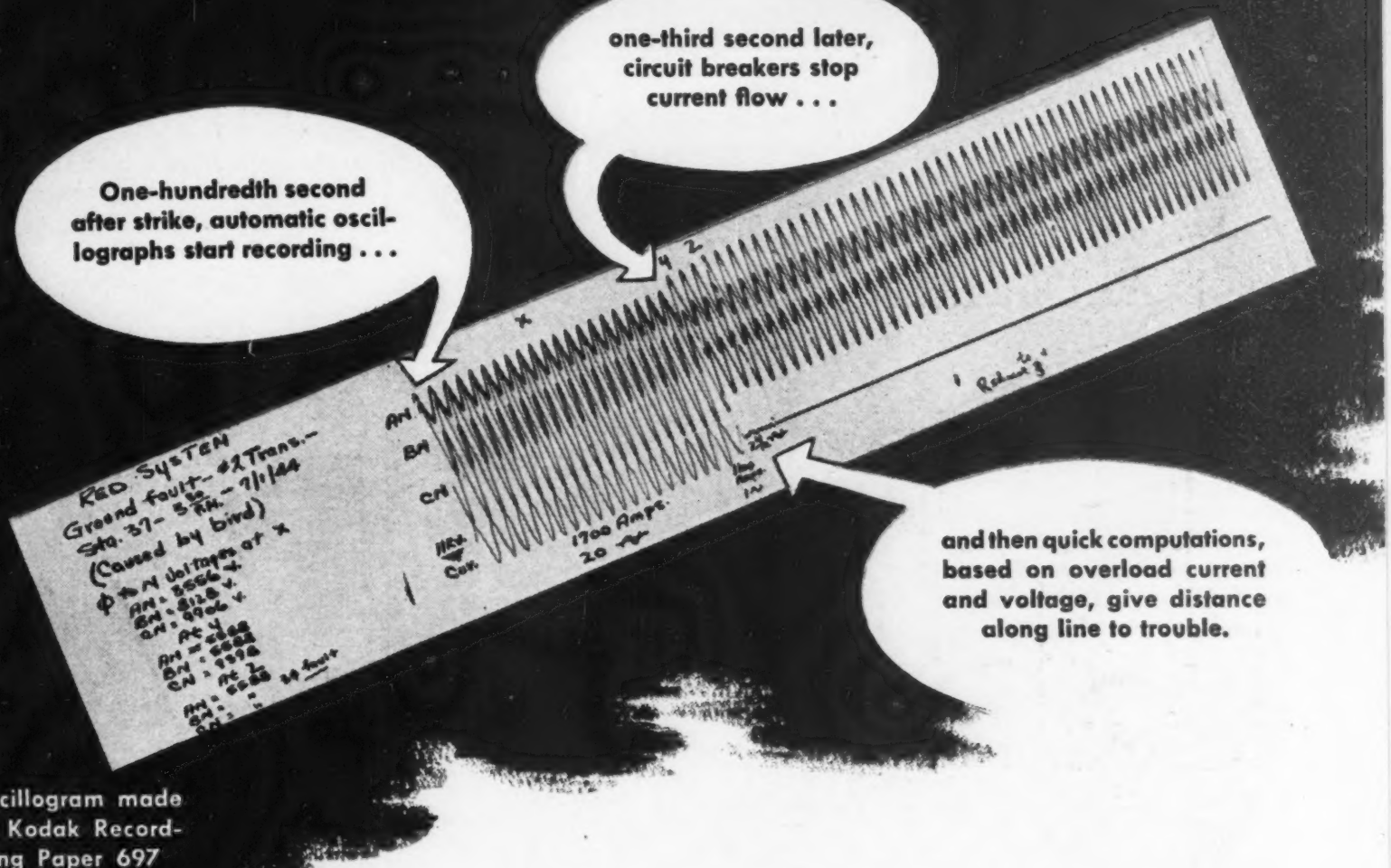
shuts off and the food is ready to eat. The power supply is located in the base of the cabinet.

It is planned to produce several sizes of equipment to meet specific applications, such as in aircraft where space is an important factor.

Phototube Sees X-Rays

AUTOMATIC X-RAY inspection of parts for internal defects is made

When POWER LINES fail...


One-hundredth second after strike, automatic oscillographs start recording . . .
one-third second later, circuit breakers stop current flow . . .
and then quick computations, based on overload current and voltage, give distance along line to trouble.
RED SYSTEM
Ground fault- #2 Trans.-
Sta. 37- 3 P.M. - 7/1/44
(Caused by bird)
Φ to N voltages at X
AN : 8668 V.
BN : 8128 V.
CN : 9946 V.
At Y
AN = 6668
BN = 6668
CN = 7398
At Z
AN = 6668
BN = "
CN = "
AN
BN
CN
1700 Amps.
20

Oscillogram made on Kodak Recording Paper 697

Instrument Recording

...another important function of photography

WHEN WINDSTORMS damage power lines . . . when animals or birds "short" a circuit to ground . . . automatic oscillographs click into action and record the current and voltage changes. In less than one-half second it may be all over—the circuit breakers will have opened to stop the flow of current.

Tremendous speed of instrument response, of recording, is essential...and moving mirror oscillographs with photographic recording papers are more than equal to the task—because they can start operating in a hundredth of a second.

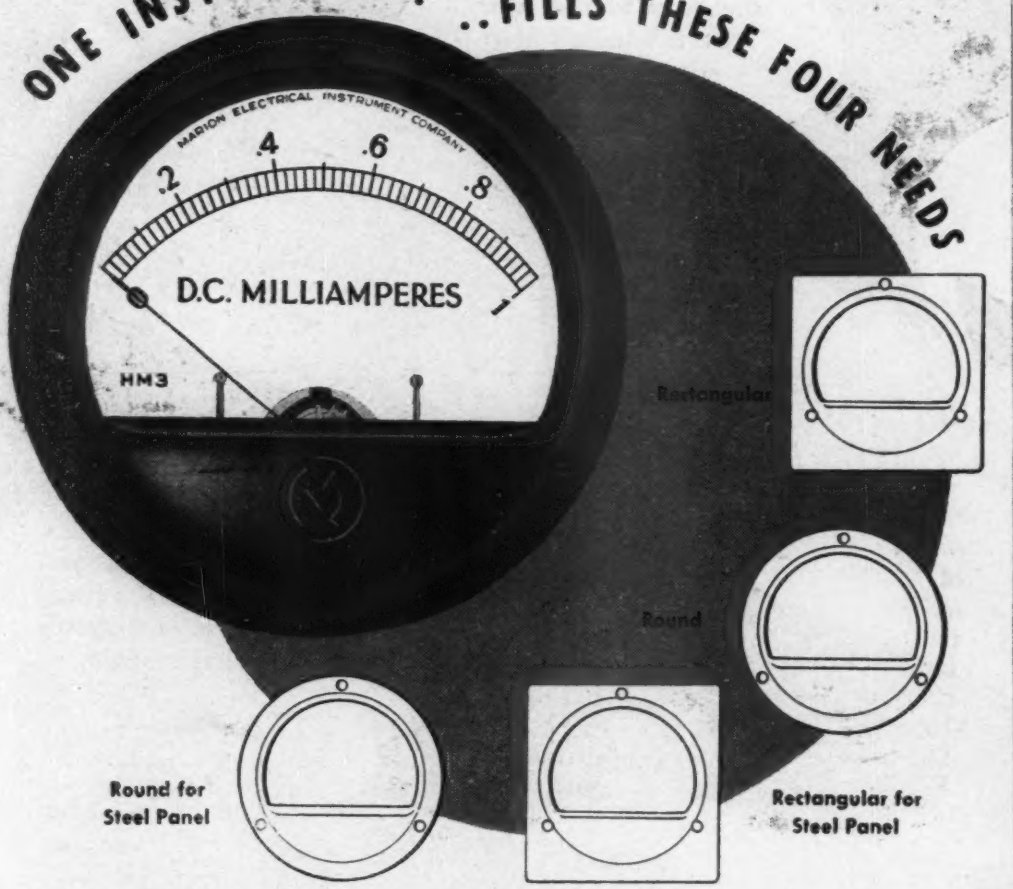
In service such as this, and in many other applications of oscillographs to studies of transient phenomena, the quality and dependability of photographic papers and films are factors which control the usefulness of trace data. There is a suitable Kodak paper or film for every type of oscillograph, and Kodak engineers will be glad to help with any work you may be doing with photographic instrument recording.

EASTMAN KODAK COMPANY
Industrial Photographic Division, Rochester 4, N. Y.

Kodak

THE "4 FOR 1" APPLICATION ADVANTAGE OF

Marion Glass-to-Metal Truly Hermetically Sealed 2½" and 3½" Electrical Indicating Instruments



Marion "hermetics" offer new flexibility in application, stocking and sales. Just one instrument, with its appropriate flanges, fills *four* different requirements . . . the only thing that's necessary is to fit the flange to the need in question. In addition to being truly hermetically sealed, these instruments are magnetically and electrostatically shielded. And are supplied with

Interchangeable Round and Square Colored Flanges

. . . which are the key to the "4 for 1" Advantage. With these, it is possible to order a minimum number of instruments in the most popular ranges, and apply either the round or square flange according to usage. This feature simplifies ordering and inventory procedures for the manufacturer . . and stocking and selling for the jobber. Besides black, the flanges are available in 12 iridescent colors — including red, blue, green, gold and silver. The use of color has been found to add to the eye-appeal and, consequently, to the sales value of otherwise drab equipment.

100% GUARANTEED

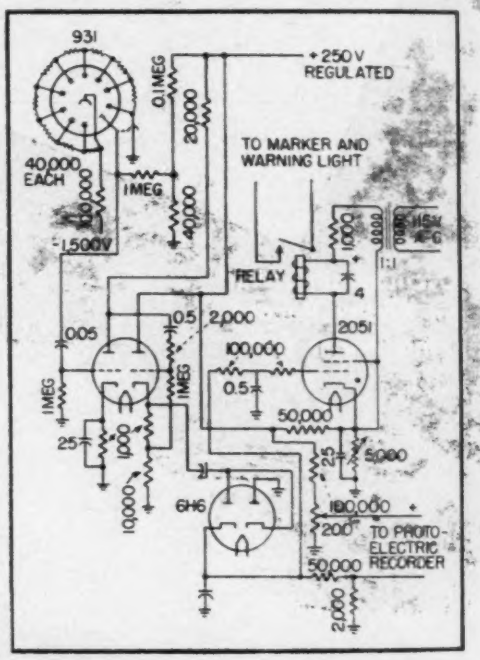
for six months — after that, regardless of condition and provided the seal has not been broken, we will replace any 2½" or 3½" instrument from 200 microamperes upward for $1.50; and 2½" and 3½" type with sensitivity greater than 200 microamperes for $2.50.

MARION ELECTRICAL INSTRUMENT CO.
MANCHESTER, NEW HAMPSHIRE
EXPORT DIVISION - 458 BROADWAY - NEW YORK 13 N.Y. U.S.A. - CABLES MORHANEX

IN CANADA: THE ASTRAL ELECTRIC COMPANY, SCARBORO BLUFFS, ONTARIO

possible in the accompanying circuit by placing a type 931 multiplier phototube in the position normally occupied by film during inspection by the x-ray absorption method, and by using an appropriate phosphor to convert the incident x-radiation into radiation of longer wavelength that can be measured by the phototube. The phosphor, such as silver-activated zinc sulphide or CaWo, may be applied to the glass envelope of the phototube or to a fluoroscopic screen positioned between the tube and the part being inspected.

Negative pulses from the 931 anode are resistance-capacitance coupled to one grid of the 6SN7 tube. The amplified positive pulses are then coupled to the other triode section, which is operated as a cathode-follower impedance converter to supply a comparatively low impedance network. The output of the



A multiplier phototube replaces the usual film for high-speed automatic inspection of parts for internal defects. The thyratron operates a marker and warning light

cathode-follower is rectified by a 6H6 diode and the d-c output is used to trip a 2051 thyratron and relay to operate a marker and warning light when output reaches a certain value. The d-c current also operates a photoelectric recorder of the x-ray intensity.

In one application of the circuit, described by H. M. Smith of General Electric Co., defective fuzes had part of their powder charge missing, and they therefore allowed greater x-ray penetration than

A Directory of Electronic Components
by ERIE RESISTOR
ERIE RESISTOR has developed and manufactured a complete line of Ceramic Condensers for receiver and transmitter applications; Silver-Mica and Foil-Mica Button Condensers; Carbon Resistors and Suppressors; Custom Injection Molded Plastic Knobs, Dials, Bezels, Nameplates and Coil Forms. Complete technical information will be sent on request.
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ERIE, PENNSYLVANIA
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SPEED UP with KESTER Cored SOLDERS

● On hundreds of reconverted production lines throughout industry, Kester Cored Solders are Specification No. 1 for fast, failure-less soldering and permanently trouble-free solder-bonds.

● Fast, because Kester Cored Solders end guesswork. Flux and alloy—*right* kind and *right* quantity—are applied in *one* simple, easy operation.

● On assembly lines for electrical equipment, you'll find *Kester Rosin-Core Solder* making connections tight, for years of freedom from corrosion and terminal resistance. Electrical circuits operate with a minimum of service difficulties when they're protected with Kester Rosin-Core Solder.

● *Kester Acid-Core Solder,* for general work, is the ideal all-purpose solder.

● Kester Cored Solders come in a wide range of flux and alloy combinations, strand and core sizes, one of which is exactly suited to every application. Kester engineers, backed by 47 years of laboratory research and practical solder experience, will gladly work with you on any solder problem, at no obligation to you. Write them fully, any time.

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good fuzes. The 2051 thyratron bias was so adjusted that sufficient signal would be obtained to trip it and operate the relay whenever a defective fuze passed through the x-ray beam. The signal from a good fuze was of insufficient amplitude to trip the circuit. Since the x-ray beam was masked off between fuzes, no x-rays reached the detector circuit except through the fuze under inspection.

To provide a check on the proper functioning of the inspection equipment, every fourth fuze passing through the test position was known to be defective. (These known defective fuzes were left in their positions on the conveyor during the entire test run.) If the equipment failed to reject any of them the test was immediately stopped and the cause of the failure eliminated.

In place of the photoelectric detector, an ionization chamber might have been used. However, the current output of an ionization chamber is usually extremely small, and considerable amplification is necessary, together with a coupling resistance of high value. This high resistance and the associated capacitances of the ionization chamber and the amplifier result in too long a time constant for high speed of response. Furthermore, the complexity and instability of these amplifiers makes it much more convenient to use the photoelectric arrangement. Even for direct-current outputs, the enormous d-c amplification with stability available in the 931 tube makes its use preferable to that of the ionization chamber in most applications.

Electronic Heating Conference

INDUSTRIAL APPLICATIONS of high-frequency heating equipment that ranged from dielectric baking of foundry cores to inhibition of mold on Boston brown bread were discussed recently at a two-day conference of engineers in San Francisco.

Baking of foundry cores was a cooperative venture between Induction Heating Corp. and E. F. Houghton Corp., suppliers of the

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LATHER with diminishing costs.

TINNERMAN NEWS EXTRA

CLEVELAND, NOVEMBER, 1946

TH YEAR OF INNERMAN PROGRESS

76TH YEAR OF TINNERMAN PROGRESS

BUYERS GET HOT TIP

MASS PRODUCTION OF NEW SERIES SPEED NUTS RESPONSIBLE FOR LOWEST PRICES IN HISTORY

Buyers Determine Savings by Checking Present Purchases of Threaded Nuts and Lock Washers

It is a simple matter to determine the savings made in the assembly of any product by converting to C7000 Series Speed Nuts.

Buyers are simply taking count of the number of threaded nuts and lock washers used daily on machine screws and sheet metal screws. For example, one manufacturer using 18,000 threaded nuts and lock washers found that the total cost exceeded 5 million a year. The annual net saving by changing to spring-tension Speed Nuts ran into a substantial figure. Conversion was made immediately. In addition to saving on the per thousand, converting to Speed Nuts also gave the advantage of time saving. Speed Nuts are applied faster, reduced weight, it lowered transportation charges and it corrected the old problem of vibration loosening.

Then too, in many assemblies space is limited. A Speed Nut can be applied where the space is too small to apply threaded nuts and lock washers without tedious, time wasting delays.

Even if the C7000 Series Speed Nuts cost more than threaded nuts and lock washers, they would still cut down the total net assembly cost. But with their lower price, the savings are still greater. Assembly of product using machine screws and sheet metal screws in any of the ten most popular sizes.

The C7000 Series Speed Nuts are accurately heat treated, and given a rust resisting finish. The live action spring steel locks the screw with a firm grip. Loosening is fully prevented because the tough spring steel not absorbs the vibration which causes loosening of conventional threaded nuts.

Billions of Speed Nuts have proved their work on hundreds of mass production products for more than a decade. The time to cut costs is now. Every day's delay is money in savings otherwise effected.

NEW SPEED NUTS HAVE RUST-RESISTING FINISH

The corroding and rusting of ordinary threaded nuts presents a serious problem in connection with servicing and replacing parts. Nuts must be chiseled or sawed off. Having no

Shrewd, alert, cost-conscious John Buyer, speaking today for American Industry, admitted wide affect of latest Tinnerman Announcement. He predicted that, "The new C7000 Series Speed Nuts, costing

Speed Nuts may be used on porcelain enamel, glass or plastic assemblies *without danger of breakage.* They provide the spring tension necessary for tight assembly, but are sufficiently resilient to prevent damage due to expansion and contraction, vibration or shock.

The *wide bearing surface* of the Speed Nut spreads the fastening load over a much greater area than does an ordinary threaded nut. Therefore, the use of separate spanner washers is unnecessary. Here again there's a saving in cost and assembly time.

Speed Nuts are *self-locking*, for their unique spring action provides a positive lock that prevents vibration loosening. Thus, the use of separate lock washers is completely eliminated. You save the cost of the washers and the time

SPEED NUTS ELIMINATE LOCK WASHERS

With the use of C7000 Speed Nuts, the lock washer necessary and obsolete. The purpose of the lock washer is to supply a spring-tension between the threaded nut and the bearing part. With the spring-tension incorporated in the Speed Nut, only one part is necessary instead of two. Only one part to purchase, one part to handle. In addition to this, the Speed Nut affords a spring-tension that cannot be secured with a lock washer and nut. And Speed Nuts never have to be chiseled or sawed off. There's no expensive delay on the assembly line because of lost time. For Speed Nut damage, when Speed Nuts are used. For Speed Nuts have spring-tension resiliency prevents tightening parts to such a degree that they might crack or chip.

Speed Nuts are also insurance against damage in transit. Your products are subject to severe vibration and shock while being packed, handled and shipped. Speed Nuts provide a resiliency that cushions and protects porcelain enamel and glass assemblies against damage.

Eliminating a lock washer not only cuts the number of parts in half but it also cuts the work in half. The Speed Nut also has a wider bearing surface. That feature also prevents distortion of the panel or part to which the nut bolds.

When you cut down the amount of buying you reduce stocking problems and handling problems. You save on transportation charges and you have a nut that does a more satisfactory holding job.

Greater Strength is Result of 20 Years of Engineering Experience

Back of the C7000 Series is all the experience of the Tinnerman factories and their extensive engineering development department. For more than 20 years the Tinnerman organization has devoted itself to studying and solving assembly problems. No other record of engineering development in this field.

Shrewd, alert, cost-conscious John Buyer, speaking today for American Industry, admitted wide affect of latest Tinnerman Announcement. He predicted that, "The new C7000 Series Speed Nuts, costing less than threaded nuts plus lock washers, will save hundreds of thousands of dollars, as well as give impetus to better and faster assembly of mass production products". From Cleveland comes word that large stocks are on hand for immediate delivery. Prices and samples of the new Speed Nuts can be had for the asking.

Speed Nuts®

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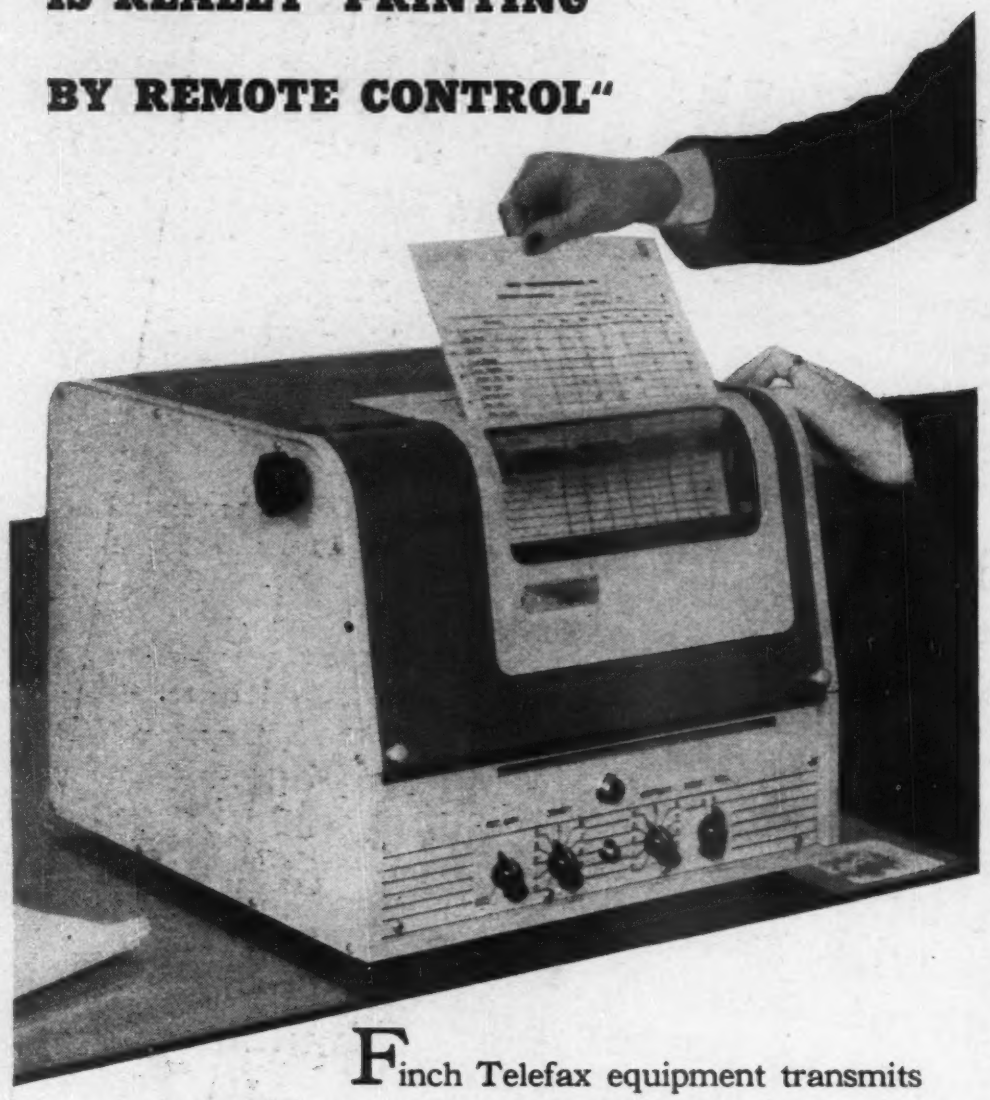
TINNERMAN PRODUCTS, INC. • 2106 FULTON ROAD • CLEVELAND 13, OHIO

finch TELEFAX

IS REALLY "PRINTING BY REMOTE CONTROL"



Finch Telefax equipment transmits and records—by radio or telephone—exact facsimiles of written or printed messages, as well as drawings, photographs, signatures, typewriting, etc. Finch Telefax is really "printing by remote control." It is the fastest known and most accurate system of communication.

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Makers also of Facsimile Broadcast Transmitting Equipment, Facsimile Home Recorders, Faxograph Duplicating Machines, and Finch Rocket Antenna for FM stations.

finch *First in Facsimile*

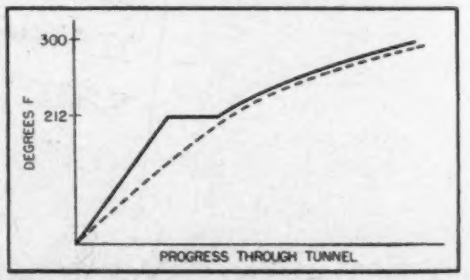
binder materials used. Where the old oven method required time in the order of hours and produced cores with irregular texture, the new development cut the operation on one particular core to 30 seconds and produced uniform cores with ideal color and texture.

The wet cores were carried through a dielectric heating tunnel by belt and timing was thus removed from the responsibility of the operator. Because of the drying curves, as shown in the accompanying illustration, it became impossible to burn the cores even by repeated passes through the tunnel. The knee in the solid curve, representing the wet pass, is created by the presence of moisture. On a subsequent pass approximately the same ultimate temperature is reached.

It has been found possible to pour alnico and Stellite around cores produced by the electronic process. The reported cost for power is about $1.25 per ton of sand treated and tube cost is eight cents per hour.

R-F Sterilization

In a discussion on r-f treatment of foods and agricultural products, it was mentioned that such treatment could be uniform only in homogeneous materials where a constant voltage gradient could be expected. Contrary to common expectations, even foods like potatoes present structures organized into discrete areas which make this difficult. Unsolved problems in this field include use of higher frequencies, application of more power, and a better understanding of tissues involved.



Drying curves for dielectric heating of foundry cores show that same ultimate temperature is reached by second pass through heating unit. Knee in solid curve is produced by moisture in initial core. Dashed curve is that of subsequent pass

The proper degree of sterilization required for commercial food

Cut design costs and maintenance expense

with CONSTANT VOLTAGE protection

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Write for Bulletin DCV-102

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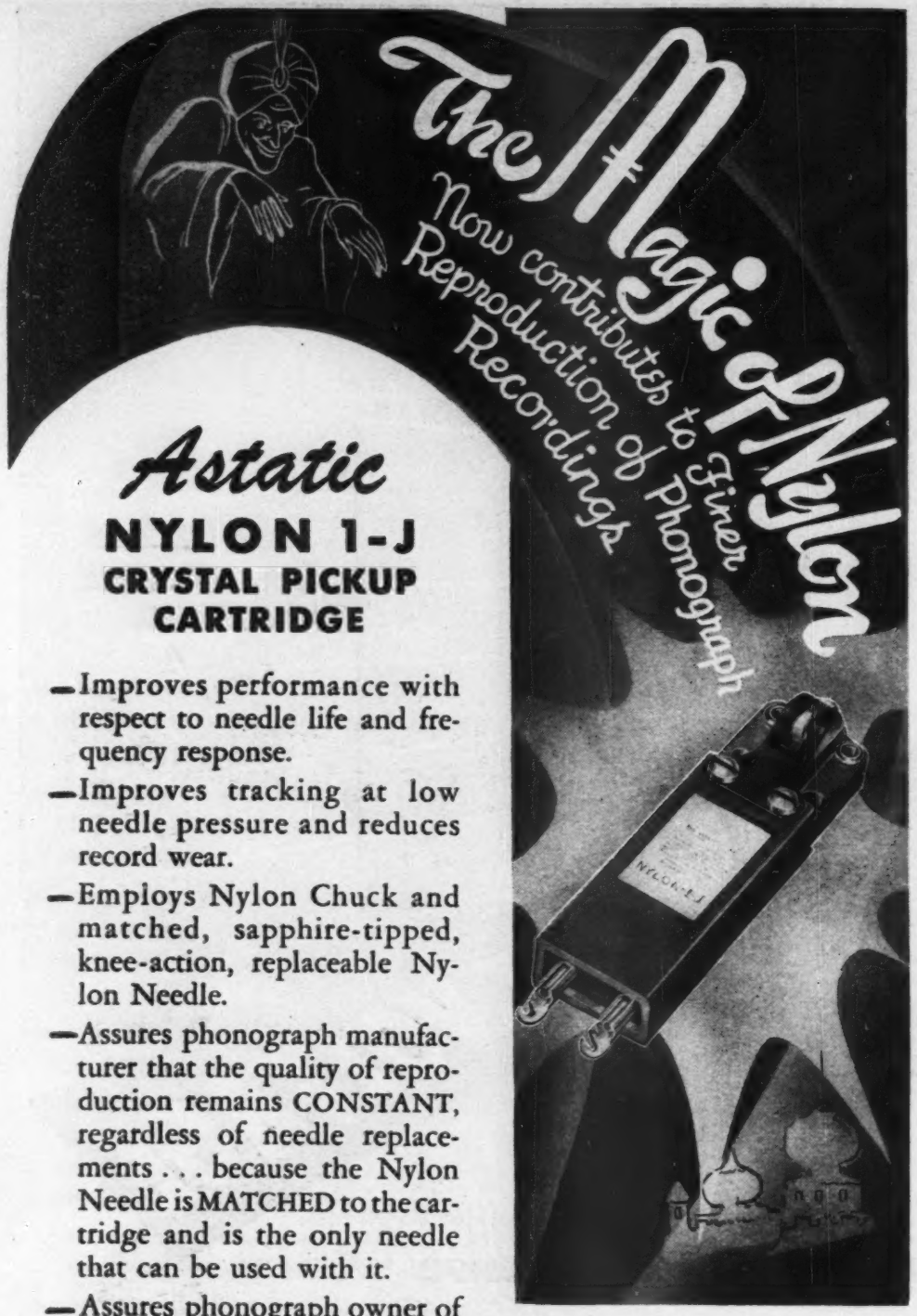

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products was stated, in one of the 14 papers delivered, to result in destruction of all spoilage microorganisms except a few of the thermophilic bacteria and inactivation of all the well-known enzymes. This may be achieved more readily with acid products than non-acid which require a considerable length of treatment in the range 240 to 260 F to destroy the heat-resistant spores of spoilage bacteria.

One speaker contrasted the possibility of using a lethal effect from electronically produced radiation without heat against the practice of using electronic means to generate heat within the product. The latter he dismissed as economically infeasible, stating that necessary equipment might very well approach in investment the entire cost of a conventional cannery. Admitting that the prospect of achieving sterilization by radiation without heat is most attractive to the industry because it would permit the production of fresher foods with uncooked characteristics, he questioned the present possibility of gaining commercial sterilization in this way.

Research Needed

Naming as possible types of radiation, ultraviolet, x-rays, electromagnetic radiation, and cathode rays, he listed barriers to the application of research work referred to in the current literature. For instance, where r-f radiation has been shown to be 100 per cent effective in killing E. coli, this was only possible in a salt-free medium. Presence of only a few hundredths of one percent of sodium chloride prevented such action and indicated that the presence of electrolytes in many foods would make them unsuited to such treatment. His conclusion was that the canning industry would find it necessary to await the outcome of further research being conducted at a number of institutions before going further in this development.

In another paper, it was disclosed that work conducted in the microbiological laboratory of the University of Southern California may indicate that there is an r-f effect on microorganisms beyond the

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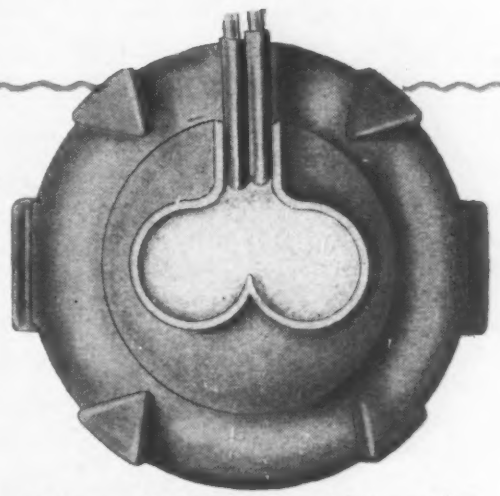

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Short lengths of Fibron #5373 are used to protect the conductor leads on the heating element of the Electra-Serve, manufactured by Electrical Industries, Inc., Newark, N. J. This bottom view of the unit shows where the hot cement seals over the #5373 insulation. Withstanding this heat and high operating temperatures, #5373 tubing retains its flexibility and high dielectric strength.

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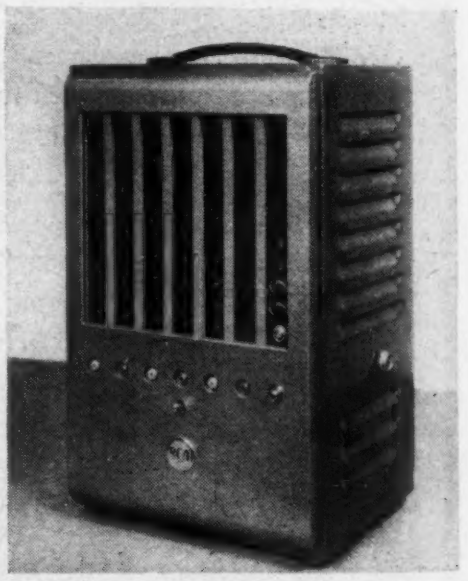
purely thermal one and that the mechanism of cell destruction under such conditions where the walls are punctured has been observed. That there is a specific frequency for each organism or group seems probable. As a practical application of the laboratory activities, successful inhibition of the growth of mold on the surface of commercial Boston brown bread with a treatment by r-f induction heating was described. The conference was sponsored by fifteen local organizations, including IRE, AIEE, and the West Coast Electronic Manufacturers Association.

High-Speed Counter

COUNTING OBJECTS at rates as fast as 1,000,000 per second, the RCA time interval counter is now for the first time being produced in quantities for science and industry. The unit was developed by RCA during the war and used for measuring projectile velocities at the Army's Aberdeen Proving Grounds. Redesigned for peacetime applications, it can be used to measure velocities and accelerations for intervals up to one second in steps of one microsecond, or to count at



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Industrial X-Ray Building

THE FIRST REPORTED use of a 2,000,000-volt x-ray machine for examining welds in pressure vessels will be that at Babcock and Wilcox Company of Barberton, Ohio. The company manufactures steam generating equipment and is a pioneer in the use of x-ray to detect flaws in pressure vessel welds, having 11 such machines now in use.

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The equipment was purchased from General Electric X-Ray Corporation, and is capable of operating at any voltage from 1,000,000 to 2,000,000.

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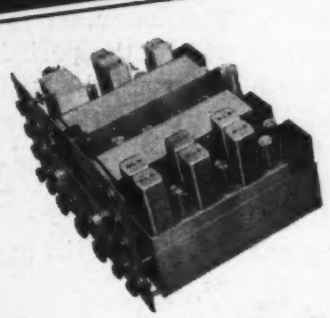

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THE ELECTRON ART

Edited by FRANK ROCKETT

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Analysis of Linear Sweep Generator

By EUGENE L. LANGBERGH

Randal Morgan Laboratory
University of Pennsylvania
Philadelphia, Pa.

THE CIRCUIT herein described is designed to take advantage of current feedback to cause a capacitor to charge very linearly through a vacuum tube. The basic circuit is shown in Fig. 1. Capacitor C is charged by current flowing through V_1 and R from the B-supply. Tube V_2 is a switch used to discharge C;

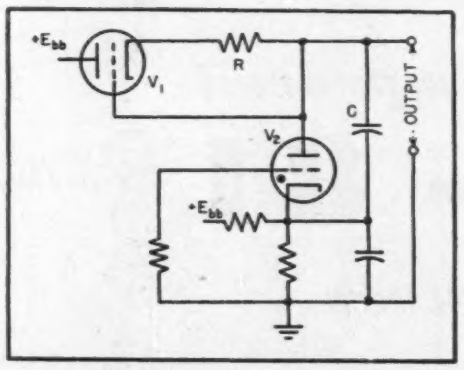

FIG. 1—Basic circuit of relaxation sweep generator to which current feedback has been added to improve the linearity

in this case a gas tube as in the usual relaxation oscillator. Current feedback upon which the circuit's linearity depends occurs in resistor R.

Mathematical Analysis

For considering the circuit mathematically, it can be simplified to that shown in Fig. 2A. From this circuit we can draw the equivalent circuit shown in Fig. 2B. We will take as $t = 0$ the time at which the switch opens and consider what happens for one cycle, all others being the same.

Assuming that negligible current is drawn by the load on the output, the mesh equation for the circuit is

$$E_{bb} - \mu E_g = r_p i + Ri + \int (i/C)\, dt$$

but $E_g = Ri$ so we have

$$E_{bb} - \mu Ri = r_p i + Ri + \int (i/C)\, dt$$

Transposing, multiplying through by C and gathering terms, we have

$$CE_{bb} = C(R + \mu R + r_p)i + \int i\, dt$$

Because $i = dq/dt$ and $i \int dt = q$, we can write an equation in q, the charge on the capacitor

$$CE_{bb} = C(R + \mu R + r_p)\frac{dq}{dt} + q$$

Let $C(R + \mu R + r_p) = A$ and rewrite the foregoing equation as

$$\frac{dq}{dt} + \frac{q}{A} = \frac{CE_{bb}}{A}$$

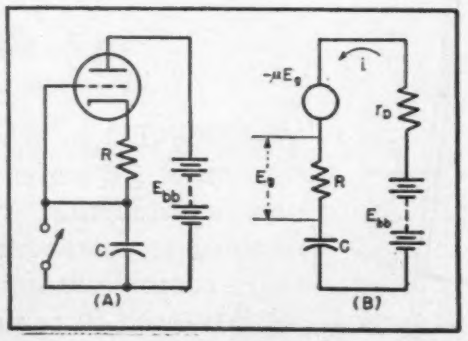

FIG. 2—(A) Simplified circuit of linear sweep generator (B) equivalent circuit of generator

This equation is in the well known form

$$\frac{dy}{dx} + Py = Q$$

the solution of which is

$$ye^{\int P\, dx} = \int e^{\int P\, dx} Q\, dx + C_1$$

We have $P = 1/A$, $Q = CE_{bb}/A$, $y = q$, $dx = dt$. Making the proper substitutions and carrying out the indicated integrations, we have

$$q = CE_{bb} + C_1 e^{-t/A}$$

at $t = 0$, $q = E_0 C$ where E_0 is the voltage at which the gas tube goes out, therefore $C_1 = C(E_0 - E_{bb})$ and the solution is

$$q = CE_{bb} + C(E_0 - E_{bb})e^{-t/A}$$

Taking the derivative, we have

$$\frac{dq}{dt} = -\frac{C}{A}(E_0 - E_{bb})e^{-t/A}$$

$$= \frac{C}{A}(E_{bb} - E_0)e^{-t/A}$$

Putting in the value of A, our result becomes

$$\frac{dq}{dt} = \frac{E_{bb} - E_0}{R + \mu R + r_p} \exp \frac{-t}{C(R + \mu R + r_p)}$$

It is evident that for dq/dt to be constant, $C(R + \mu R + r_p)$ must be large. This fact controls the selection of the tube V_2. It should be a high-μ tube with large r_p. High-μ pentodes fulfill this condition best. However, the circuit worked fairly well even with a low-μ triode but large R.

Degree of Nonlinearity

The question of just how badly nonlinear the sweep may become can be answered in the following manner. The maximum value of t per cycle will be the period of the sawtooth determined by the potential at which the gas tube ignites. If E_i is the voltage on the capacitor at ignition, then $q_i = CE_i$. Putting this value into the equation for q and solving for the maximum value of $t = T$

$$CE_i = CE_{bb} + C(E_0 - E_{bb})e^{-T/A}$$
$$(E_{bb} - E_i) = (E_{bb} - E_0)e^{-T/A}$$

$$e^{-T/A} = \frac{E_{bb} - E_i}{E_{bb} - E_0}$$

$$T = -A \ln \frac{E_{bb} - E_i}{E_{bb} - E_0}$$

Note that $\ln(E_{bb} - E_i)/(E_{bb} - E_0)$ is always negative because $(E_{bb} - E_i)/(E_{bb} - E_0)$ is always less than unity, hence T is always positive.

Solving for A gives

$$A = -\frac{T}{\ln \frac{E_{bb} - E_i}{E_{bb} - E_0}}$$

then

$$\frac{dq}{dt} = \frac{C}{A}(E_{bb} - E_0) \exp \frac{T}{t} \ln \frac{E_{bb} - E_i}{E_{bb} - E_0}$$

The maximum value of t/T is unity at $t = T$. The charging rate at $t = T$ is

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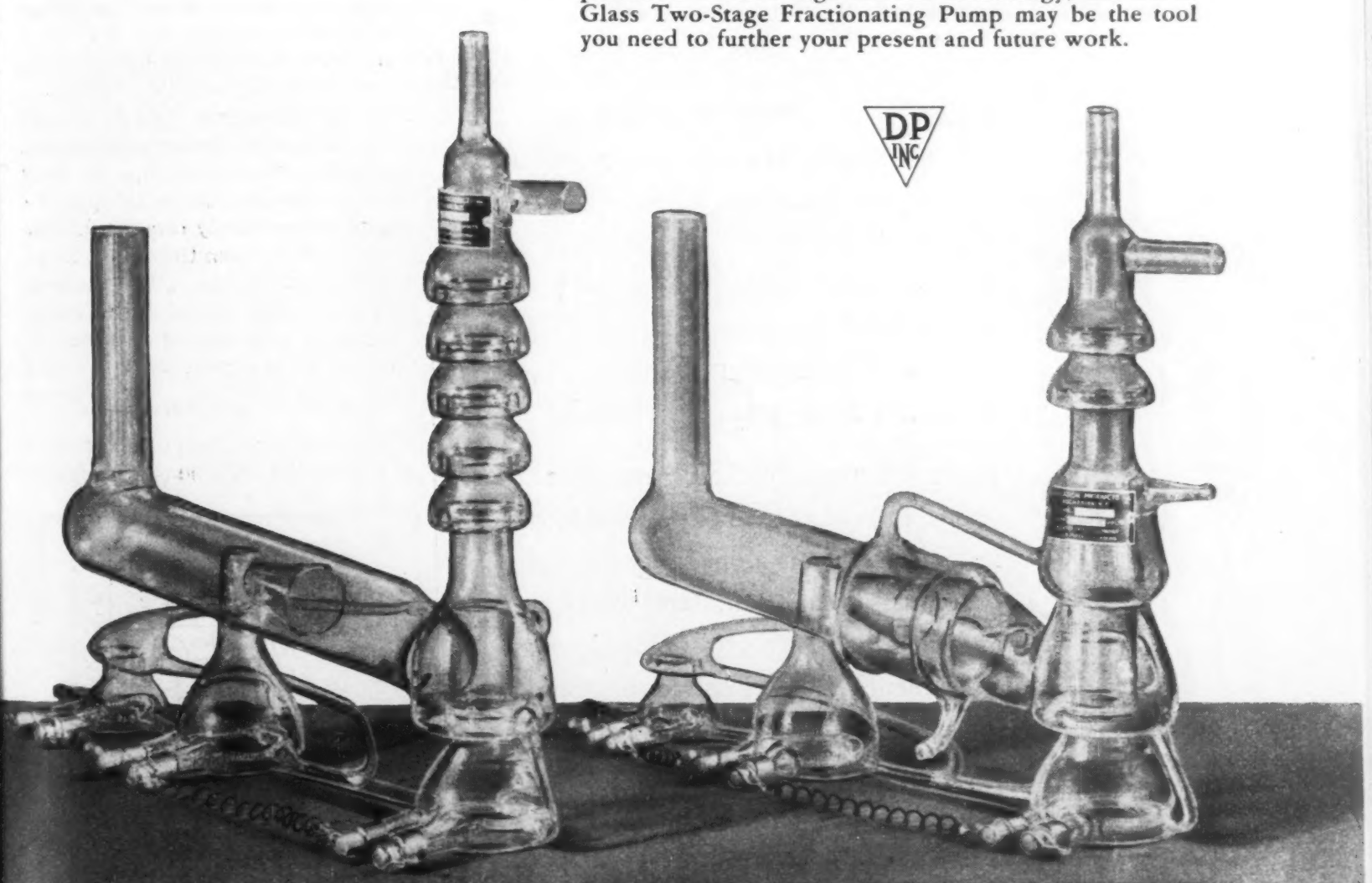

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$$\left.\frac{d}{dt}\right|_T = \frac{C}{A}(E_{bb} - E_0) \exp \ln \frac{E_{bb} - E_i}{E_{bb} - E_0}$$

which represents the worse possible condition of nonlinearity. Because it is reasonable to expect the sawtooth to be amplified before being placed upon the cathode-ray tube, the sweep generator need put out a voltage no greater than 10 volts. This condition means that $E_i - E_0 = 10$ volts. Using reasonable values of $E_{bb} = 350$ volts, $E_0 = 15$ volts, and $E_i = 25$ volts, exp ln $(E_{bb} - E_i)/(E_{bb} - E_0)$ has a value of 0.970 at the most nonlinear part of the cycle. For all practical purposes then, the charging current is linear through the whole cycle.

Returning to the period of oscillation and putting in the value of A, we have

$$T = -C(R + \mu R + r_p) \ln \frac{E_{bb} - E_i}{E_{bb} - E_0}$$

the ln $(E_{bb} - E_i)/(E_{bb} - E_0)$ is a negative constant so we can write $T = C(R + \mu R + r_p)k$. It is evident that we can change C for coarse frequency selection and vary R for fine frequency control. However, because of the large current feedback, good values of μ are not easily obtainable, hence the period cannot be accurately calculated. It is also evident from the circuit that synchronization can be accomplished in the normal fashion by applying synchronizing voltage to the grid on the gas tube V_2.

Laboratory Sweep Generator

The circuit put into use is shown in Fig. 3. The 50,000-ohm resistor

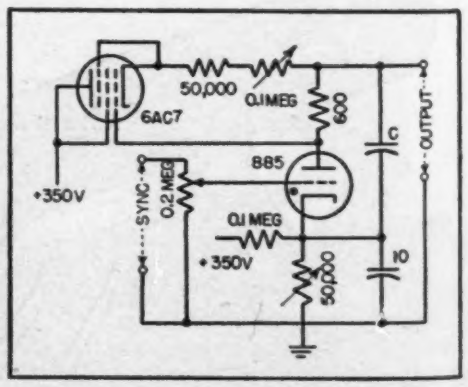

FIG. 3—Complete circuit of laboratory sweep generator whose output is linear

in series with the cathode of the 6AC7 gives a minimum value of R. The 0.1-meg rheostat is the fine frequency control. The value of C is changed in five steps from 0.1 μf to 0.0001 μf giving a wide frequency

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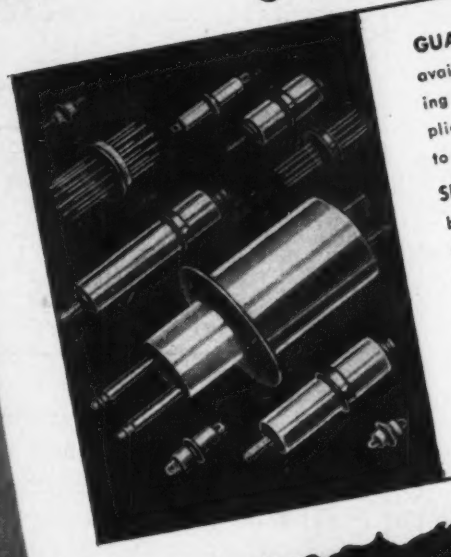

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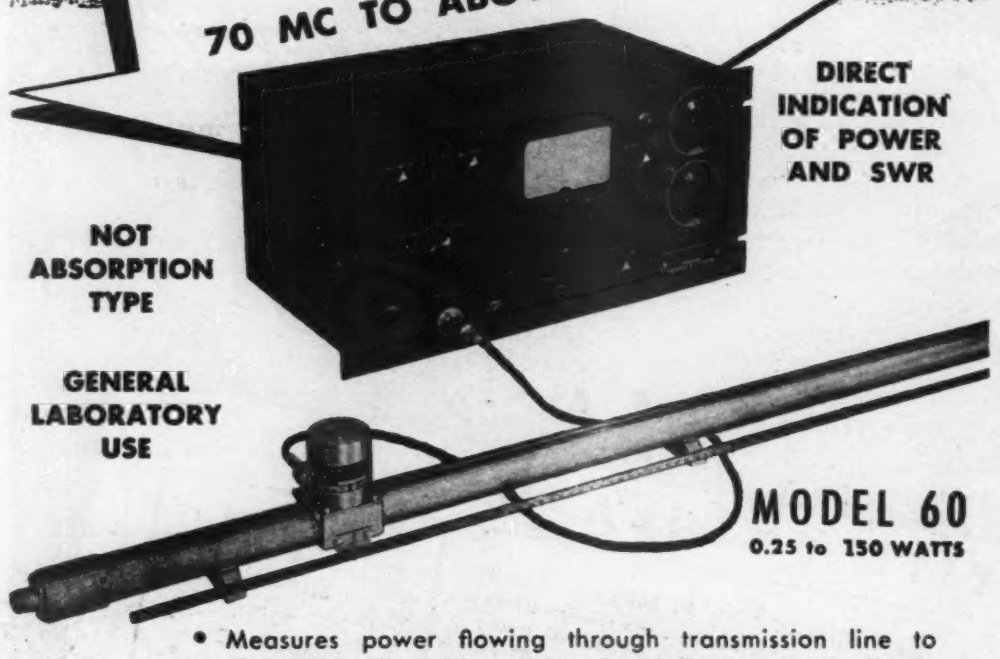

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range. Table I shows obtainable ranges. The 600-ohm resistor protects the 885 from excessive currents and improves the charging to discharging time ratio. It does so by developing a large negative bias on the 6AC7 during the discharge of C through the 885. This bias permits the voltage across C to drop

Table I—Frequency Ranges

Capacitance in μf	Frequency range in cps
0.5	40– 165
0.1	70– 450
0.2	300– 1,900
0.005	1,200– 7,500
0.001	4,000–25,000
0.0001	22,000–50,000

more rapidly than it would if current were allowed to flow from the B-supply during discharge.

The fixed bias was so adjusted that the output voltage was about 10 volts. The generator was found to make possible very high sweep frequencies with good front to back trace ratio and little change in amplitude with frequency.

The circuit as described is a relaxation oscillator which generates a very linear sweep. However, the principle developed can be used to produce high-speed linear sweeps of low repetition rates or even sweeps for transient observation. If the gas triode V_2 is replaced by a vacuum tube at zero bias, the vacuum tube will short the capacitor C. The sweep is then generated only when a negative pulse is applied to the grid of this vacuum tube thus cutting it off. The length of the sweep will be determined by the length of the pulse. The only precaution necessary is that the pulse should not be made so long that the sweep amplitude $E_i - E_o$ will become large and make exp ln $(E_{ss} - E_i)/(E_{ss} - E_o)$ take on values so much less than unity that the sweep will become intolerably nonlinear.

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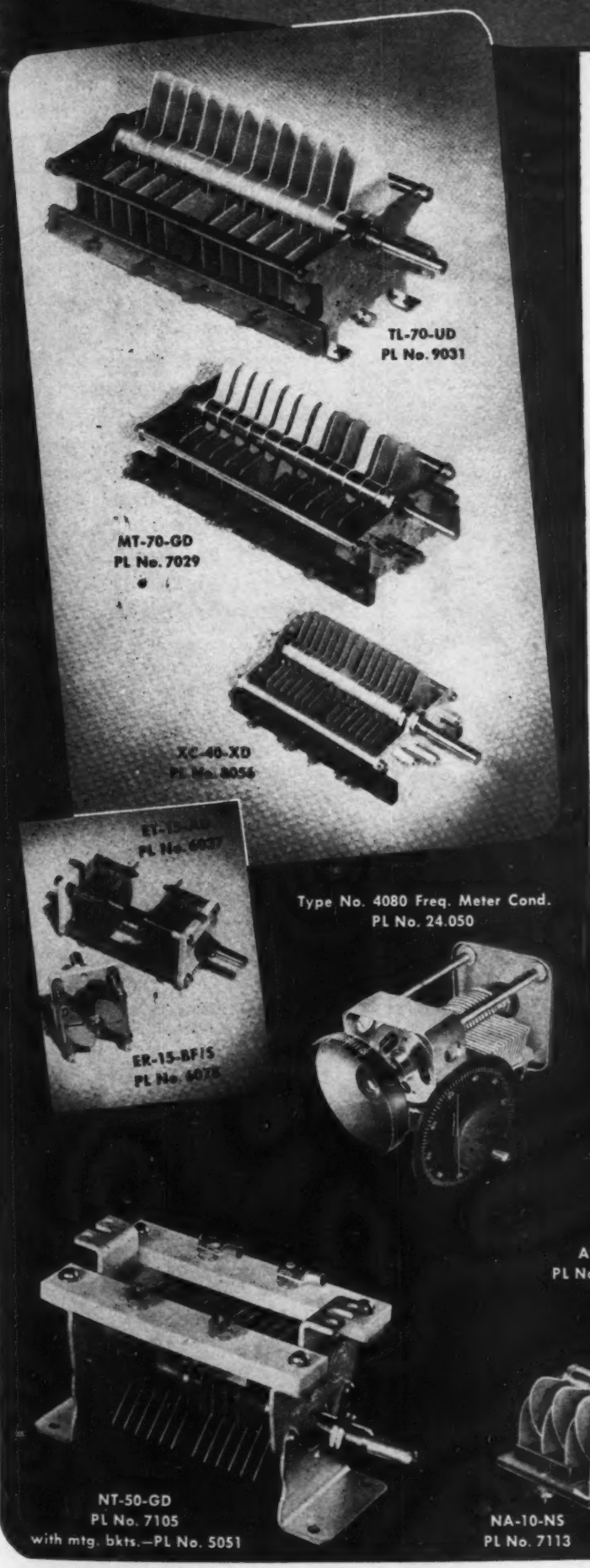

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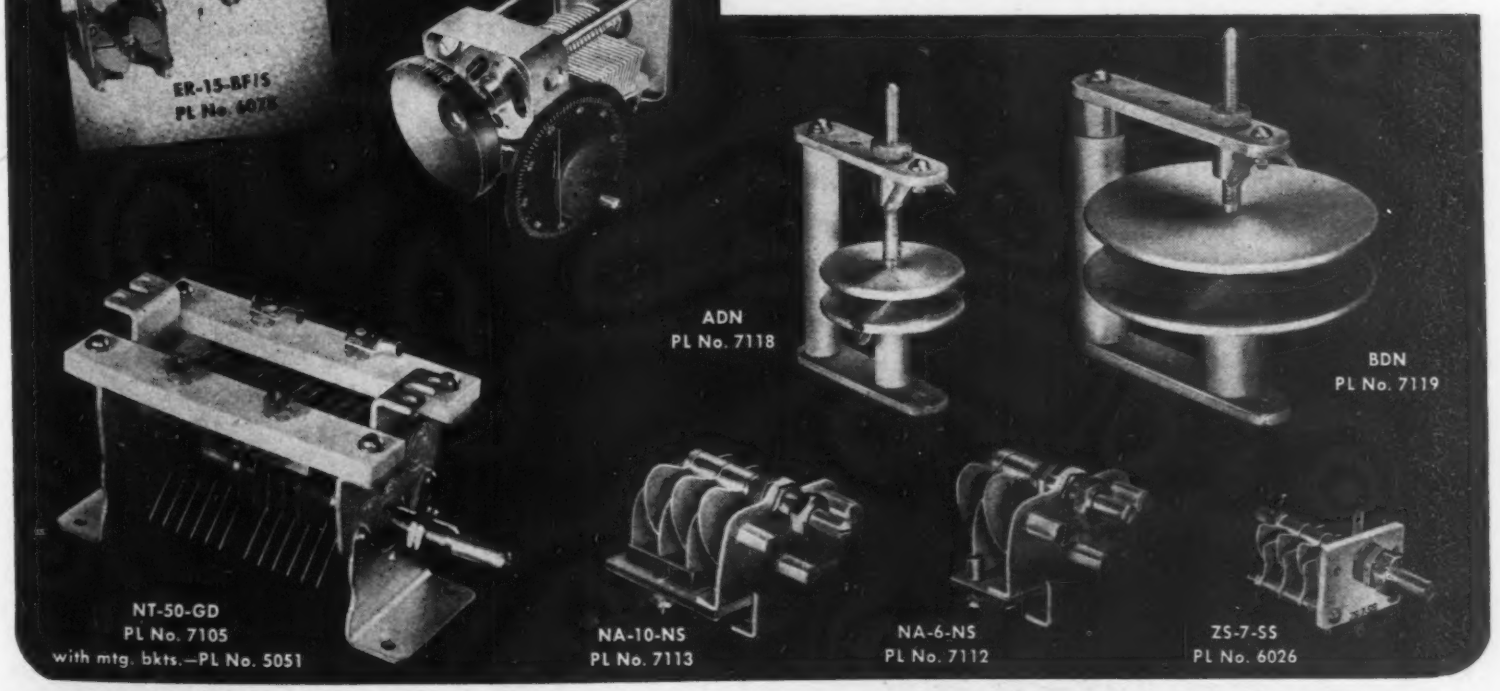

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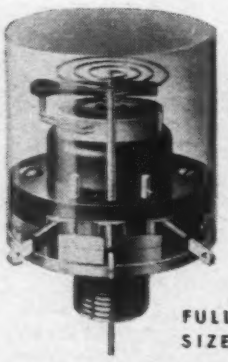

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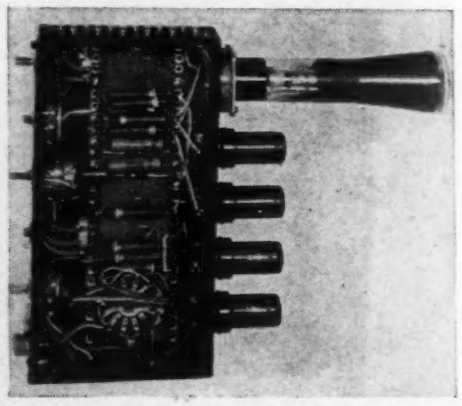
tronics, held its first national technical conference and product exhibit at Pittsburgh, Pa., September 16-20. Concurrently with the conference, the Industrial Instruments and Regulators Division of the ASME and the Physical Society of Pittsburgh held meetings.

Use of instruments for production and product control including material on computers, gaging, pressure and vibration metering, aviation instrumentation, and controls for atomic research was described. To those attending the meeting, several overall impressions were clear. Although this was a meeting of operating engineers, much of what was said is of interest to design engineers. Several chairmen and speakers stressed the need for greater collaboration between instrument designers and the users. In fact, there is considerable delay, six to eight years in some instances, between the time the design of electronic equipment is described and

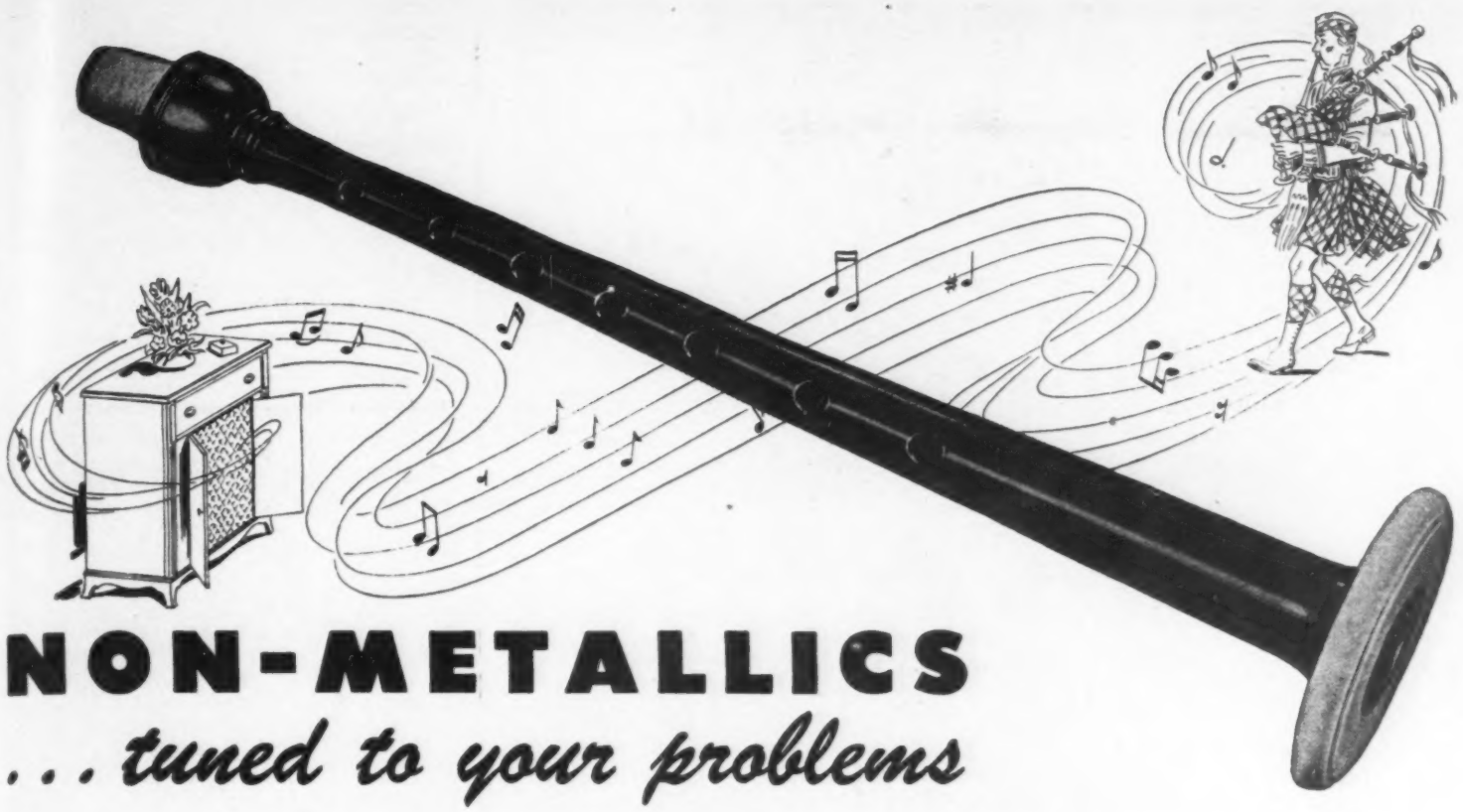


One channel of the six channel, cathode-ray oscillograph developed at the Naval Ordnance Laboratory and described at the "Instrumentation for Tomorrow" conference of the Instrument Society of America. The two-inch cathode-ray tube is driven by a resistance coupled, balanced amplifier. Continuously moving film records trace

the time the equipment is used to an appreciable extent. Although evaluations of the utility of electronic instruments differed from field to field, it was universally voiced that what is needed is a high gain, wide band, d-c amplifier that is free from all forms of drift.

The Donutron

A SQUIRREL-CAGE MAGNETRON, called a donutron, provides a simpler, less



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expensive construction than cavity magnetrons, is less subject to mode jumping, and operates over its tunable range at a single anode voltage. The interleaved finger construction of the anode is shown in Fig. 1.

The donutron can be made to oscillate in a variety of modes, however only the resonant cavity mode

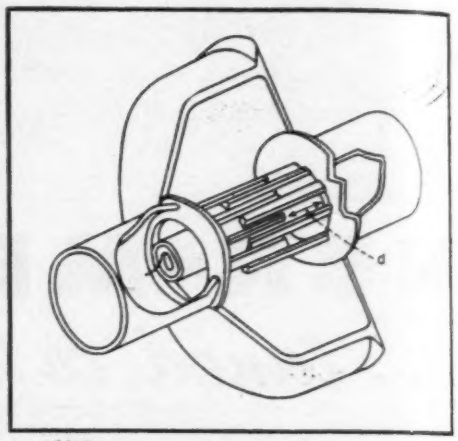


FIG. 1—Squirrel-cage magnetron is tuned by varying the distance by which the two sets of interleaved bars overlap each other

and the capacitively loaded re-entrant line modes are currently important. Further investigation of these and other modes may increase the realizable frequency and power output of the tube. In the re-entrant line mode, a standing wave forms circumferentially about the anode. In this mode, about 50 watts at 45 percent efficiency have been obtained; anode current ranges from 100 to 200 ma, static impedance from 700 to 1,500 ohms. The tube can be tuned over a 1.5 to 1.0 frequency range.

Field Pattern

The two end rings, from which the fingers of the squirrel-cage extend, form the re-entrant line. The fingers provide the capacitive loading. Thus the main radio-frequency current flows in the rings themselves, only enough current flows in the fingers to charge them to the potential of the ring at their individual points of attachment. The wavelength is twice the electrical circumference of the anode ring.

The out-of-phase radio-frequency currents in the two rings are accompanied by magnetic fields that form closed loops interlacing the squirrel-cage bars as shown in Fig. 2. Voltage nodes appear where the maximum lines of magnetic flux pass between pairs of teeth. This

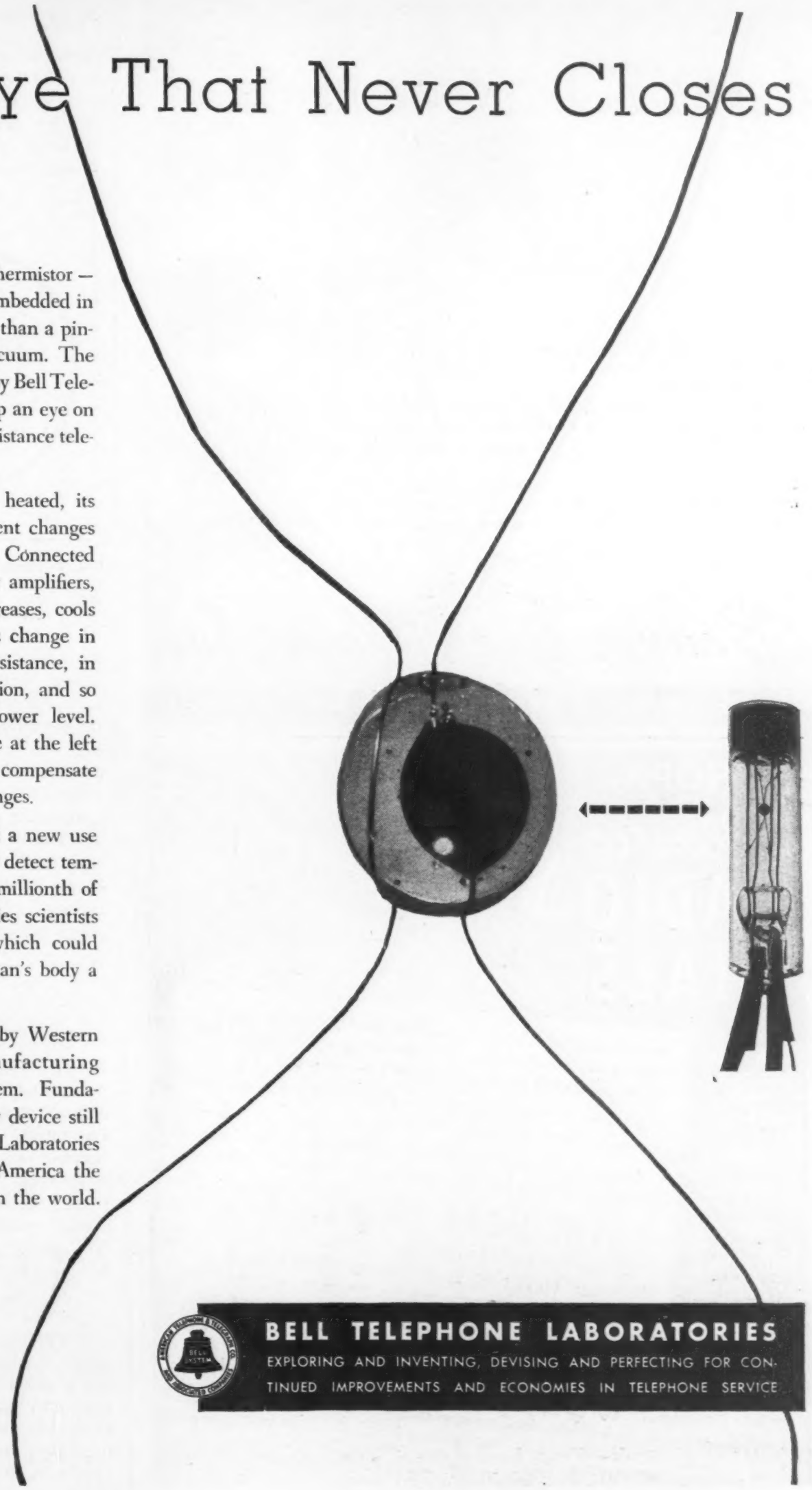
The Eye That Never Closes

You are looking at a thermistor — a speck of metallic oxide imbedded in a glass bead hardly larger than a pinhead and mounted in a vacuum. The thermistor was developed by Bell Telephone Laboratories to keep an eye on the amplification in long-distance telephone circuits.

When a thermistor is heated, its resistance to electric current changes rapidly. That is its secret. Connected in the output of repeater amplifiers, it heats up as power increases, cools as power decreases. This change in temperature alters the resistance, in turn alters the amplification, and so maintains the desired power level. Current through the wire at the left provides a little heat to compensate for local temperature changes.

Wartime need brought a new use for this device which can detect temperature changes of one-millionth of a degree. Bell Laboratories scientists produced a thermistor which could "see" the warmth of a man's body a quarter of a mile away.

Thermistors are made by Western Electric Company, manufacturing branch of the Bell System. Fundamental work on this tiny device still continues as part of the Laboratories program to keep giving America the finest telephone service in the world.



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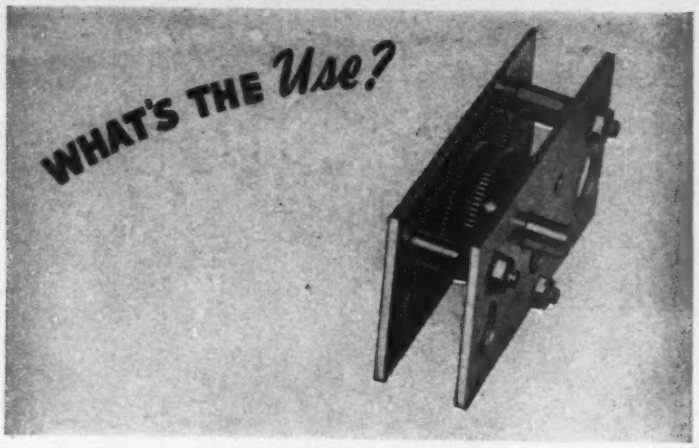

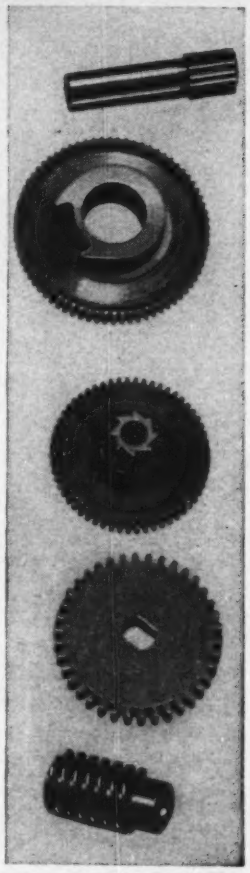

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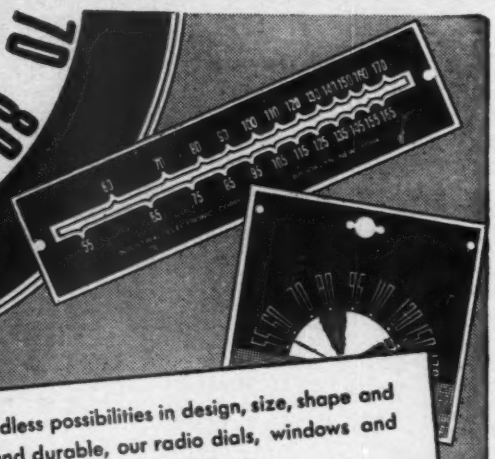

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distribution was verified by exploring the field of the cold, externally excited tube with a probe from a dummy cathode. When the tube is being excited by an electron stream, two such patterns that are

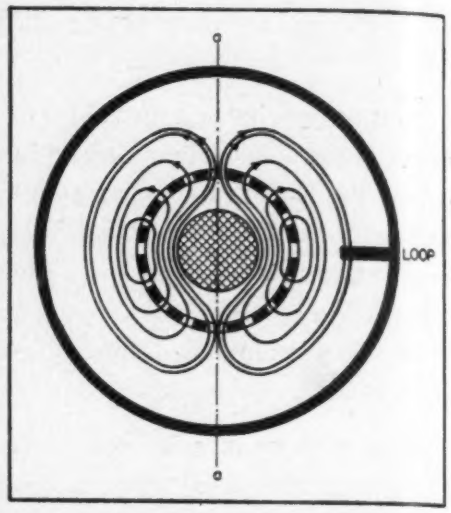

FIG. 2—Because the magnetic field links the squirrel cage, the size of the tube shell cavity does not appreciably affect the resonant frequency

mutually perpendicular are established in the radial plane of the tube. Were it not for unavoidable irregularity of the tube construction, the two fields would be degenerate. Additional overlapping extensions are added to further remove the one field from the other. (A Tunable Squirrel-Cage Magnetron by F. H. Crawford and M. D. Hare, Radio Research Laboratory, Harvard University, an unpublished report.)

Stenotrone

A GAS TUBE having a stricture in the path of the discharge between cathode and anode produces high-frequency, high-powered oscillations. The tube is called a stenotrone. The electric discharge itself, independent of a resonant circuit, generates undamped electric oscillations. Under these conditions the tube becomes very hot.

Characteristics

Frequency, amplitude, and waveshape of the generated oscillations are affected by the tube's geometry, type and density of the gas, current, and external circuit. The oscillation consists of a periodic variation in current, during which

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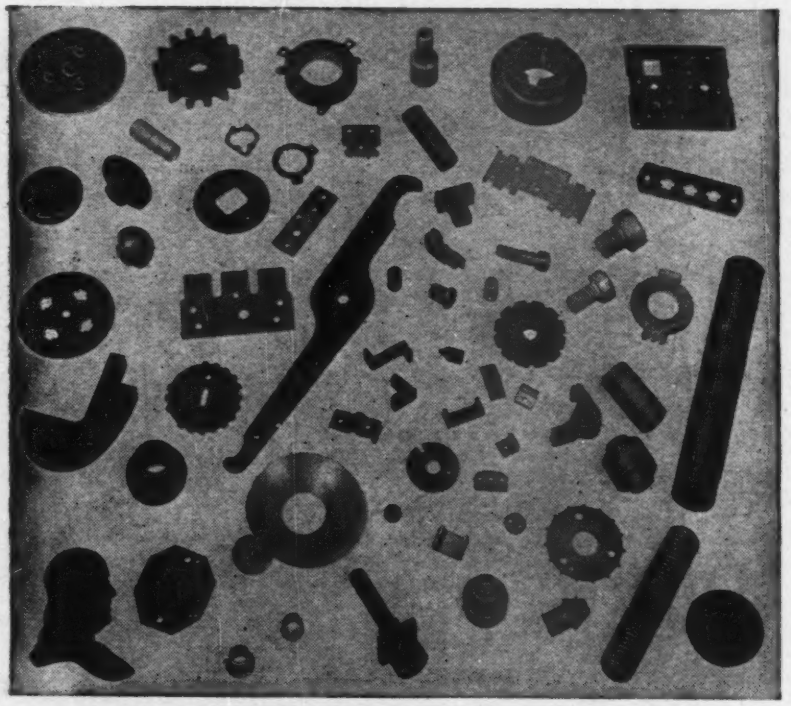

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the current may become zero but never reverses. There is a maximum degree of pulsation for a critical vapor pressure, and for tube temperature. The greater the external resistance or the supply potential, the greater the strength of oscillations. The larger the aperture placed in the path of the discharge, the higher the upper limit to which the current swings. There is a critical position between cathode and anode for the aperture (which is necessarily a dielectric) at which weakest oscillations are produced — of significance for designing mercury rectifiers.

The observed phenomena can be explained as interruption of the current in the arc by rarefaction of gas in the neck of the discharge. Theory indicates that the current strength that causes interruption is proportional to the product of the aperture area and the gas pressure, which is confirmed by measurements.

To utilize the oscillations, a load can be either inductively or capacitively coupled to the external circuit, inductive coupling being preferred. Using mercury vapor at a pressure of about one millimeter of mercury and at a temperature around 20 C, oscillations between 15 and 100 kc were obtained. One kilowatt of output power was obtained at approximately 65-percent efficiency from a 240-volt source. (The Generation of High-Power Electric Oscillations by a Low Pressure Discharge, by B. L. Granovsky and T. A. Suetin, *Comptes Rendus*, 1945 No. 6, p 410.)

Cathode Follower of Very Low Output Resistance

A POSITIVE SQUARE WAVE applied to the input of a conventional cathode follower has its leading edge well reproduced, but its trailing edge is badly distorted. A two-tube circuit that overcomes this fault has an output impedance of 30 ohms at frequencies up to 30 mc and an output voltage that is higher than with a single-tube circuit.

Circuit Operation

To develop the two-tube circuit, consider a two-stage, resistance-

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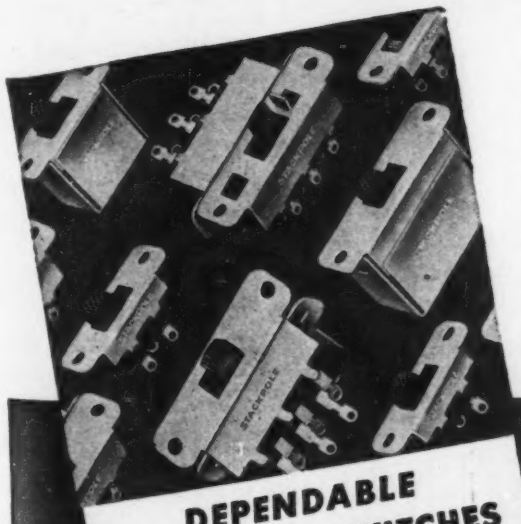

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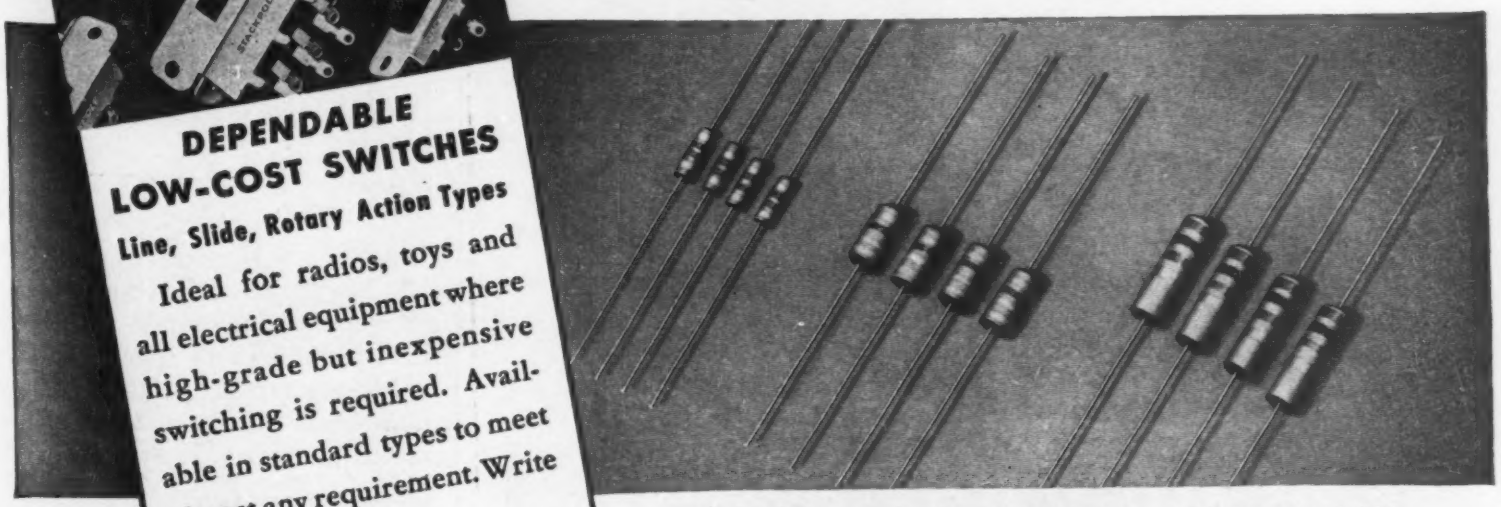

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coupled amplifier with 100-percent feedback from the second tube to the first as shown in Fig. 1A. The cathode resistor R_k must be large

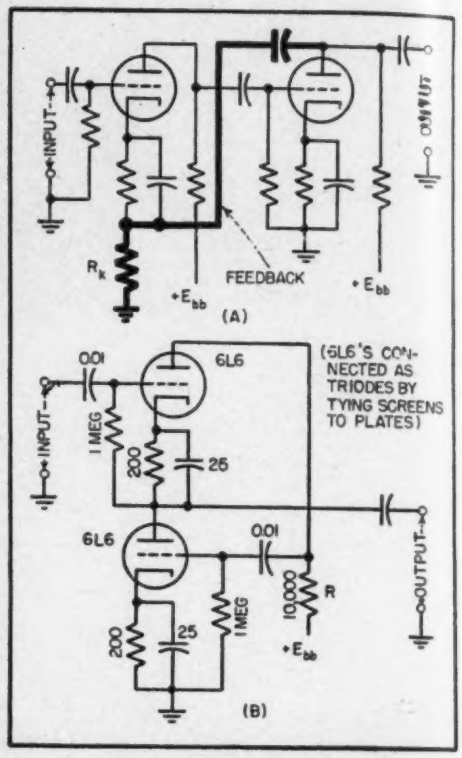


FIG. 1—By rearranging a two stage feedback amplifier (A) the plate resistance of the second tube can serve as the cathode resistor in the stage of the first tube (B)

not to unduly decrease the gain of the second stage. The cathode degeneration in the first stage is therefore large. If R_k is of the order of the plate resistance of the tubes employed in the circuit, one of the tubes could be substituted for R_k as at Fig. 1B, which is the new circuit under discussion.

The equivalent circuit for that of Fig. 1B is shown in Fig. 2. Analysis of this circuit indicates that the ratio of output to input voltages is

$$\frac{E_{out}}{E_{in}} = \frac{\mu^2 + \mu\,(r_p/R)}{(\mu^2 + \mu + 1) + (\mu + 2)\,(r_p/R)}$$

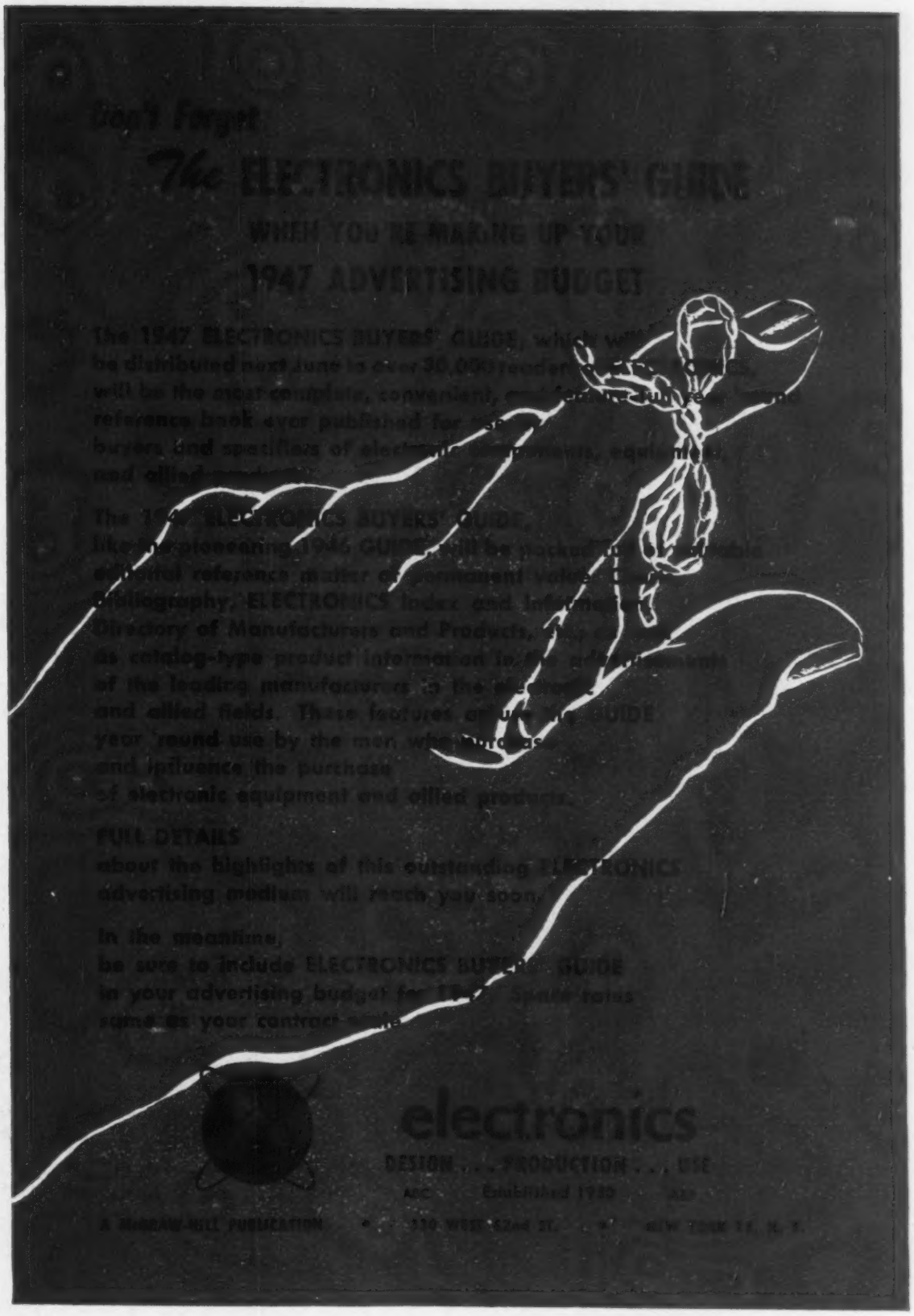
and the output conductance is

$$G_{out} = \frac{1}{R_{out}} = \frac{\mu + 1}{r_p + R} + \frac{1 + \frac{\mu\,(\mu + 1)}{(r_p/R) + 1}}{r_p}$$

When R is large compared to r_p the first term of the conductance equation becomes negligible and the second term becomes approximately equal to the product of the amplification factor of the tube and the transconductance

$$G_{out} = (\mu^2 + \mu + 1)/r_p \approx \mu g_m$$

The value of output conductance represents an improvement over


Don't Forget
The ELECTRONICS BUYERS' GUIDE
WHEN YOU'RE MAKING UP YOUR
1947 ADVERTISING BUDGET
electronics
DESIGN . . . PRODUCTION . . . USE

Of course in your particular industry they may only be "mole hills" but whatever their size they represent loss in manpower, time, money and material.

To meet the ever-growing need for exact materials-inspection the HYPERSONIC ANALYZER* was developed to "see through solids with sound".

- For non-destructive testing of solid materials
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the conventional cathode follower by the factor μ. However, in driving low load impedances from this circuit, the signal must be small enough not to overdrive the lower tube.

Circuit Characteristics

The circuit with the values shown in Fig. 1B was examined at various frequencies from 10 kc to 30 mc. The output approached

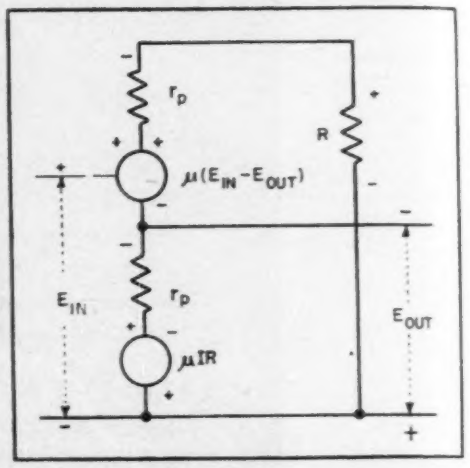

FIG. 2—Equivalent circuit of the low output impedance cathode follower

unity as the output load approached 1,000 ohms. The output was essentially uniform to about 10 mc, but fell above that frequency, falling faster with lower load resistances. A pronounced rise in output (an actual voltage gain) was obtained with a capacitive load of 0.0001 μf at approximately 10 mc. The rise occurred at lower frequencies as the capacitive load was increased. With 0.01 μf there was a slight rise at about 800 kc and practically no response at 1,000 kc. The fidelity of response to a pulse was definitely superior to that of a single-tube circuit and the effect on sine waves was also good. (Cathode Follower by Calvin M. Hammack, Report 469, Radiation Lab., MIT, Cambridge, Mass.)

Extending Thyratron Life

HYDROGEN CLEANUP in such hydrogen thyratrons as the 5C22 shortens the life of the tube. To reduce this loss of gas, tube parts are made from as pure nickel as is obtain-

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But Low Cost too"

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SHEET . . . Available with precious metal on one side, both sides or wholly covered, inlaid and edge laid in practically any combination of precious to base metal. Base to base metal combinations also available.

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HIGH VACUUM PUMPS

FOR HIGH PUMPING SPEED AND LOW ABSOLUTE PRESSURE

In the new vacuum coating units now being developed by Distillation Products, Inc., Rochester, N. Y., two 110 cubic foot Kinney pumps are used for rapid pump down and backing the Distillation Products, Inc., diffusion pumps. The illustration also shows four Kinney Vacuum Tight Valves which are used on all types of systems where "no leakage" is of utmost importance. Everywhere . . . in this country and abroad . . . Kinney High Vacuum Pumps meet the heavy demands of large scale process operations — exhausting lamps and tubes, sintering metals, producing penicillin, and performing countless other operations in modern vacuum processing. Kinney Single Stage Vacuum Pumps produce and maintain low absolute pressures to 10 microns; Compound Vacuum Pumps to 0.5 micron.

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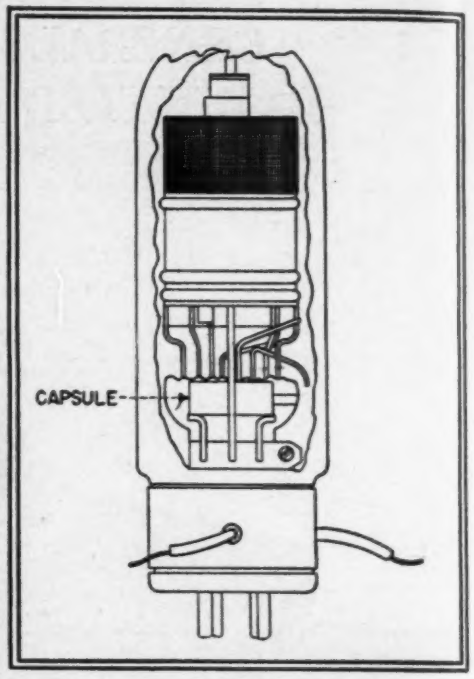
Horrocks, Roxburgh Pty., Ltd., Melbourne, C. I. Australia
W. S. Thomas & Taylor Pty. Ltd., Johannesburg, Union of South Africa

We also manufacture Liquid Pumps, Clutches and Bituminous Distributors

able. However, as cleanup proceeds, the gas pressure is lowered and the tube characteristics change.

To maintain the gas pressure despite absorption by nickel parts, a titanium hydride powder hydrogen generator was developed. The powder is placed in a heated cap-



With a hydrogen generating capsule located inside 5C22 thyratrons, greater life and higher pulse rates were possible

sule. As hydrogen is absorbed throughout the tube, the capsule makes up the loss, giving satisfactory thyratron operation for a life of at least 2,000 hours. In addition, the hydrogen generator enables the tube to be made of impure nickel (Hydrogen Generator for Electron Tubes, by Harold W. Gerlicher, Evans Signal Laboratory, Belmar, N. J.—Report of development, characteristics, and preparation of capsule, and tube characteristics obtained with its use).

Projection Television

TELEVISION IMAGE projection systems have been suggested by Manfred von Ardenne of Berlin, Germany (U.S. Patent 2,277,008 issued March 17, 1942; and U.S. Patent 2,297,443 issued Sept. 29, 1942—this patent is vested in the Alien Property Custodian, see ELECTRONICS, 1945, July, p 306), and by Karl Martin and Johannes

Handle is molded of sturdy Celanese* plastic; tools are of high grade alloy steel.

Contained in this Handle

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"SOCKET SCREW" KIT

with interchangeable bits

For men who like to have a complete supply of tools, yet dislike bulk and confusion, the Hallowell "Socket Screw" Kit is the answer. It is one of the neatest tricks of the year. The hollow Celanese* plastic handle holds interchangeable bits for most all purposes . . . Phillips, Hex and Flat. There is a swivel bit-chuck, which locks securely in position, and makes it possible to twirl a screw using the vertical position, and then snapping the chuck to an angle or ell position, to get the final tightening pull.

Not illustrated: "Socket Wrench" Kit; the "Auto" Kit; the "Home" Kit. Write for our 8-page booklet that fully describes these handy Tool Kits. Obtainable at Suppliers throughout the country.

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Sturdy construction (as shown in the accompanying diagram) is but one characteristic of Hi-Q Wire Wound Resistors. The others are precision winding, wide range of types, sizes and ratings and quantity production. Standard units are available in capacities from 5 to 200 watts with outside dimensions of 5/16" x 1" to 1-1/8" x 12" and resistance values up to 100,000 ohms. Where required, special units are engineered to specific jobs.

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OTHER Hi-Q COMPONENTS

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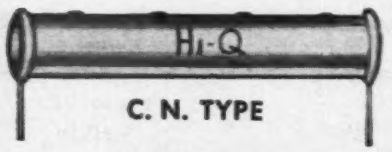
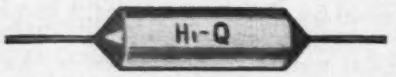
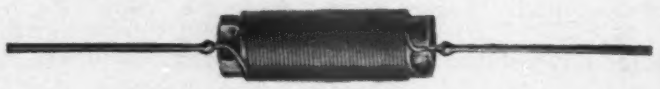


C. N. TYPE



C. I. TYPE

CHOKE COILS



STAND-OFF CONDENSERS

Hi-Q ELECTRICAL REACTANCE CORPORATION
FRANKLINVILLE, N. Y.

Flugge, Rathenow, and Hans Georg Roll of Germany (U.S. Patent 2,229,302 issued Jan. 21, 1941). This latter patent refers to lens systems for projecting and enlarging phosphorescent images. A lens, both surfaces of which are ground to the required contours, projects the image to a back-surfaced concave mirror, the front surface of which is also ground. The mirror focuses the enlarged image either directly or by a flat mirror to the viewing screen.

The other two patents cited above describe the use of zinc blend and other crystals as electronically controlled polarizing gates. When placed in a high-potential gradient and scanned by an electron beam, these high resistance crystals become charged thereby changing their rotation of polarized light. Light is projected through such a gate as shown in Fig. 1A, or reflected from the crystal as shown in Fig. 1B. The reflection technique is the better both because the light passes twice through the crystals and because optical and electrical systems can be isolated.

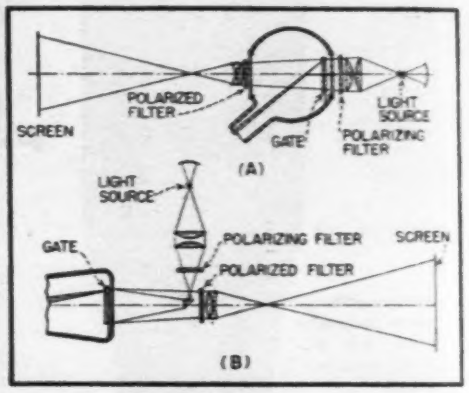
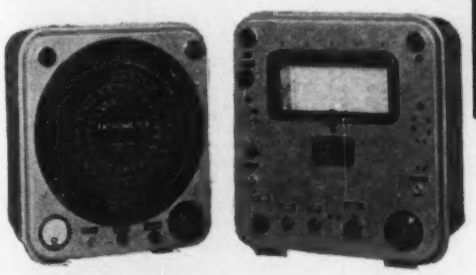


FIG. 1—Charge placed on gate by electronic scanning changes the angular rotation of the polarized light passing through the gate

Polarized light produced by filtering is projected on the charged crystal; it is reflected, its plane of polarization being altered in accordance with the electrical charge produced by electronic scanning. The reflected light is transmitted through a second polarizing filter to obtain the image. Because the system modulates an auxiliary light source and possesses image storage, it is capable of producing large, bright images. By interrupting the image mechanically, as in motion picture projection technique,

METAL PLATES that serve a steady diet of sound

There are two oscillators in every Fathometer. Opened oscillating unit shows how the all-important Nickel lamination plates are mounted.



Both an indicating dial and recorder can be used with the Fathometer. Other components include an amplifier and a driver.

The "FATHOMETER"—the first practical application of "*Sonar*"—utilizes the magneto-striction of Nickel

One of the most practical uses of sonar is the Fathometer, manufactured by the Submarine Signal Co., Boston, Mass.

The Fathometer generates sonic vibrations, throws them at the bottom, and then listens for their echoes. With a Fathometer you can map the ocean floor . . . locate fish . . . safeguard navigation.

Like many other adaptations of sonar, the Fathometer depends upon Nickel to send and receive the sonic vibrations. Heart of each oscillator is a stack of thin Nickel plates, laced together with a winding of wire.

HOW THE FATHOMETER WORKS

When current is passed through these windings, a fluctuating magnetic field is created. *That's when the magnetic-strictive property of Nickel goes to work!*

For under the influence of magnetic force, Nickel *contracts*, snapping back to its original size only when the field goes dead. By maintaining a *fluctuating* magnetic field, a steady, powerful hum can be directed to the ocean floor.

Striking a target, the sonic waves bounce back to the Fathometer, where a second oscillator (acting as a receiver) goes through the same cycle in reverse to convert sound into electrical impulses. Other components then time the lag between transmission and echo, registering the depth on an indicator.

WHY NICKEL WAS CHOSEN

Nickel is used in sonar because it contracts more than any other commercial metal, contracting 32 units of length for every 1,000,000.

Magneto-striction is just one of the specialized properties obtainable with Nickel. When specifying metals for electronic or electrical use always consider Nickel and the INCO Nickel Alloys. They are strong, tough, rustless, corrosion-resistant and thermally durable.

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von Ardenne observes, in U.S. Patent 2,276,750 issued March 17, 1942, that flicker can further be reduced so that slower frame rates and hence narrower transmission bands can be used.

UHF Measurement

STANDING WAVES are used to indicate the impedance match in high-frequency circuits. To measure these standing waves, a coaxial transmission line is formed into a circle, slotted, and combined with a probe. A probe is rotated around the loop of line and at the same time a sweep voltage is generated, by an auxiliary circuit. The rectified voltage detected by the probe, and the sweep voltage are applied to the plates of a cathode-ray tube. The tube display indicates the standing wave as a function of angular position along the line. The system can be used for continuously observing the standing waves on a transmission circuit while the circuit is adjusted. (No. 2,400,597, granted May 21, 1946 to Donald W. Peterson, Radio Corp. of America).

ATOMIC TEST AMPLIFIER

Signals from hydrophones on the hull of the target ship, increased by the Westinghouse preamplifier at the right, are transmitted by radio to a recorder miles away from Operation Crossroad. High-speed cameras in the recorder make a permanent record of pressure fluctuations

ADDITIONS and CORRECTIONS

to the

JUNE 1946–1947 ELECTRONICS BUYERS' GUIDE

The following listings are to be used in conjunction with the June 1946–1947 ELECTRONICS BUYERS' GUIDE for information on manufacturers' names, addresses, and products omitted or incorrectly listed in that issue. Product classification numbers and names are the same as used in the June Guide.

2. AUDIO FREQUENCY AMPLIFIERS
Cook Laboratories, 139 Gordon Blvd., Floral Park, N. Y.
Furst Electronics, 800 W. North Ave., Chicago 22, Illinois
Langevin Co. Inc., The, 37 West 65th St., New York 23, N. Y.
Rek-O-Kut Co., 146 Grand St., New York 13, N. Y.

5. BROADCAST STUDIO SPEECH INPUT CONTROL EQUIPMENT
Langevin Co. Inc., The, 37 West 65th St., New York 23, N. Y.

13. FACSIMILE COMMUNICATION SYSTEMS
The Western Union Telegraph Co., 60 Hudson St., New York 13, N. Y.

20. HEARING AIDS
Tayburn Equipment Co., 120 Greenwich St., New York 6, N. Y.

24. MEGAPHONES, ELECTRONIC
Tayburn Equipment Co., 120 Greenwich St., New York 6, N. Y.

25. MONITORS, BROADCAST
Langevin Co. Inc., The, 37 West 65th St., New York 23, N. Y.

31. ELECTRIC PHONOGRAPHS and RECORD PLAYERS
Aviola Radio Corp., Phoenix, Ariz.
Rek-O-Kut Co., 146 Grand Street, New York 13, N. Y.

35. RADAR NAVIGATIONAL DEVICES
Sperry Gyroscope Co., Manhattan Bridge Plaza, Brooklyn, N. Y.

39. AM COMBINATIONS
Aviola Radio Corp., Phoenix, Ariz.

42. AM TABLE MODELS
Aviola Radio Corp., Phoenix, Ariz.

76. FACSIMILE RECORDERS
The Western Union Telegraph Co., 60 Hudson St., New York 13, N. Y.

77. FILM RECORDERS
Electronic Chemical Engineering Co., 1235 E. Olympic Blvd., Los Angeles 21, Calif.

81. RECORDING AND TRANSCRIPTION TURNTABLES
Rek-O-Kut Co., 146 Grand St., New York 13, N. Y.

84. COMPLETE SOUND SYSTEMS
Audio Products Co., 2101 W. Olive Ave., Burbank, Calif.

90. U.H.F. TRANSCEIVERS
Electronic Associates Inc., 61 Brighton Ave., Long Branch, N. J.

95. BROADCAST TRANSMITTERS
Western Electric Co. Inc., 120 Broadway, New York 5, N. Y.

99. FACSIMILE TRANSMITTERS
The Western Union Telegraph Co., 60 Hudson St., New York 13, N. Y.

101. FIXED STATION COMMUNICATION TRANSMITTERS
Western Electric Co. Inc., 120 Broadway, New York 5, N. Y.

102. FM TRANSMITTERS
Western Electric Co. Inc., 120 Broadway, New York 5, N. Y.

119. COUNTERS
Electronic Associates Inc., 61 Brighton Ave., Long Branch, N. J.
Furst Electronics, 800 W. North Ave., Chicago 22, Illinois

137. PHOTOELECTRIC CONTROLS
Furst Electronics, 800 W. North Ave., Chicago 22, Illinois

138. PHOTOGRAPHIC EXPOSURE CONTROLS
Electronic Mechanical Prods. Co., 13-15-17 N. Virginia Ave., Atlantic City, N. J.
Furst Electronics, 800 W. North Ave., Chicago 22, Illinois

144. SERVO CONTROLS
Electronic Associates Inc., 61 Brighton Ave., Long Branch, N. J.

145. SMOKE DENSITY COMBUSTION and CONTROLS
Furst Electronics, 800 W. North Ave., Chicago 22, Illinois

153. WELDING CONTROLS
Raytheon Mfg. Co., Electronic Equip. Div., Waltham 54, Mass.

174. INDUCTION and DIELECTRIC HEATING
Raytheon Mfg. Co., Electronic Equip. Div., Waltham 54, Mass. (Dielectric)
Westinghouse Electric Corp., East Pittsburgh, Pa. (Induction and Dielectric)

200. ELAPSED TIME METERS
Cramer Co., R. W., Centerbrook, Conn.

207. ELECTRONIC MICROMETERS
Wilmotte Mfg. Co., 1713 Kalorama Rd. N.W., Washington 9, D. C.

222. COMBUSTION RECORDERS
Furst Electronics, 800 W. North Ave., Chicago 22, Illinois

235. AUTOMATIC INTERVAL TIMERS
Electronic Associates Inc., 61 Brighton Ave., Long Branch, N. J.
Furst Electronics, 800 W. North Ave., Chicago 22, Illinois

246. WELDING TIMERS
Weltronic Co., 19500 W. 8 Mile Rd., Detroit 19, Mich.

274. CAPACITOR ANALYZERS
Cornell Dubilier Electric Corp., 1000 Hamilton Blvd., South Plainfield, N. J.

285. BRIDGES
Measurements Corp., Boonton, N. J.

294. CHRONOGRAPHS, INERTIALESS
Furst Electronics, 800 W. North Ave., Chicago 22, Illinois

298. CAPACITY DECADE BOXES
Cornell Dubilier Electric Corp., 1000 Hamilton Blvd., South Plainfield, N. J.

309. FM SIGNAL GENERATORS
Measurements Corp., Boonton, N. J.

317. GEIGER COUNTER INDICATORS
Condenser Products Co., 1369-1375 North Branch St., Chicago 22, Ill.

321. VOLUME INDICATORS
Audio Products Co., 2101 W. Olive Ave., Burbank, Calif.

326. AMMETERS
Rek-O-Kut Co., 146 Grand Street, New York 13, N. Y.

373. CATHODE-RAY INSTRUMENTS
Furst Electronics, 800 W. North Ave., Chicago 22, Illinois

392. INSULATION TESTERS
Measurements Corp., Boonton, N. J.

401. CURVE TRACERS
Wilmotte Mfg. Co., 1713 Kalorama Rd. N.W., Washington 9, D. C.

447. RAILROAD ANTENNAE
Buggie & Co., H. H., Madison Ave. & 22nd St., Toledo 1, Ohio

450. TELEVISION & FM ANTENNAE
Buggie & Co., H. H., Madison Ave. & 22nd St., Toledo 1, Ohio

451. U.H.F. & V.H.F. ANTENNAE
Buggie & Co., H. H., Madison Ave. & 22nd St., Toledo 1, Ohio

463. BELLOWS
Cook Electric Co., 2700 Southport Ave., Chicago 14, Illinois

471. CARBON & GRAPHITE BRUSHES
National Carbon Co. Inc., 30 East 42nd St., New York 17, N. Y.

472. METAL-GRAPHITE BRUSHES
National Carbon Co. Inc., 30 East 42nd St., New York 17, N. Y.

477. METAL CABINETS
Walter Co., S., 144 Centre Street, Brooklyn 31, N. Y.

481. CABLE ASSEMBLIES
Buggie & Co., H. H., Madison Ave. & 22nd St., Toledo 1, Ohio

494. FIXED CAPACITORS
Condenser Products Co., 1369-1375 North Branch St., Chicago 22, Ill.
Cornell Dubilier Electric Corp., 1000 Hamilton Blvd., South Plainfield, N. J.

496. MICA TRANSMITTING CAPACITORS
Cornell Dubilier Electric Corp., 1000 Hamilton Blvd., South Plainfield, N. J.

499. OIL IMPREGNATED CAPACITORS
Condenser Products Co., 1369-1375 N. Branch St., Chicago 22, Ill.

502. PLASTIC DIELECTRIC CAPACITORS
Condenser Products Co., 1369-1375 N. Branch St., Chicago 22, Ill.

505. SMALL HIGH VOLTAGE CAPACITORS
Condenser Products Co., 1369-1375 N. Branch St., Chicago 22, Ill.
Cornell Dubilier Electric Corp., 1000 Hamilton Blvd., South Plainfield, N. J.

511. WAX IMPREGNATED CAPACITORS
Condenser Products Co., 1369-1375 N. Branch St., Chicago 22, Ill.
Cornell Dubilier Electric Corp., 1000 Hamilton Blvd., South Plainfield, N. J.

513. AUTOMATIC RECORD CHANGERS
Aviola Radio Corp., Phoenix, Ariz.

517. ALUMINUM CHASSIS
Olympic Tool & Mfg. Co., 37 Chambers St., New York 7, N. Y.
Walter Co., S., 144 Centre St., Brooklyn 31, N. Y.

518. AUDIO and POWER CHOKES
Langevin Co. Inc., The., 37 W. 65th St., New York 23, N. Y.

519. FILTER CHOKES
Langevin Co. Inc., The., 37 W. 65th St., New York 23, N. Y.

520. HERMETICALLY SEALED CHOKES
Airdesign Inc., 241 Fairfield Ave., Upper Darby, Pa.

522. TEST & TUBE CLIPS and CLAMPS
Fahnestock Electric Co. Inc., 46-44 Eleventh St., L. I. City 1, N. Y.

529. MULTIPLE WOUND COILS
Airdesign Inc., 241 Fairfield Ave., Upper Darby, Pa.

531. POWER and A.F. COILS and WINDINGS
Burnell & Co., 10-12 Van Cortlandt Ave. East, Bronx 58, N. Y.

532. R.F. and I.F. RECEIVING or TRANSMITTING COILS
Burnell & Co., 10-12 Van Cortlandt Ave. East, Bronx 58, N. Y.

538. CABLE CONNECTORS and COUPLINGS
Buggie & Co., H. H., Madison Ave. & 22nd St., Toledo 1, Ohio

540. CERAMIC CABLE CONNECTORS
Buggie & Co., H. H., Madison Ave. & 22nd St., Toledo 1, Ohio

541. COAXIAL CABLE CONNECTORS
Buggie & Co., H. H., Madison Ave. & 22nd St., Toledo 1, Ohio

543. RECEPTACLE CONNECTORS
Buggie & Co., H. H., Madison Ave. & 22nd St., Toledo 1, Ohio

572. IF FILTER CRYSTALS
Bliley Electric Co., Erie, Pa.

576. QUARTZ CRYSTAL ULTRASONIC
Bliley Electric Co., Erie, Pa.

577. RECEIVER CONTROL CRYSTALS
Bliley Electric Co., Erie, Pa.

579. SUPERSONIC CRYSTALS
Bliley Electric Co., Erie, Pa.

599. BAND PASS FILTERS
Electronic Associates Inc., 61 Brighton Ave., Long Branch, N. J.

602. EQUALIZER FILTERS
Burnell & Co., 10-12 Van Cortlandt Ave. East, Bronx 58, N. Y.

609. COIL FORMS
Buggie & Co., H. H., Madison Ave. & 22nd St., Toledo 1, Ohio

621. WIRE HARNESSES
Buggie & Co., H. H., Madison Ave. & 22nd St., Toledo 1, Ohio

622. HEADPHONES and HEADSETS
Tayburn Equipment Co., 120 Greenwich St., New York 6, N. Y.

623. HEADS, RECORDING
Rek-O-Kut Co., 146 Grand St., New York 13, N. Y.

633. SPEAKER PROJECTOR HORNS
Langevin Co. Inc., The, 37 West 65th St., New York 23, N. Y.

637. PUBLIC ADDRESS SYSTEM HOUSINGS
Langevin Co. Inc., The, 37 West 65th St., New York 23, N. Y.

650. INSULATING FOIL
Buggie & Co., H. H., Madison Ave. & 22nd St., Toledo 1, Ohio

654. MOLDED INSULATION PARTS
Buggie & Co., H. H., Madison Ave. & 22nd St., Toledo 1, Ohio

655. PLASTIC INSULATION PARTS
Buggie & Co., H. H., Madison Ave. & 22nd St., Toledo 1, Ohio

707. LUGS and TERMINALS
Patton-MacGuyer Co., 17 Virginia Ave., Providence 5, R. I.

716. METAL STAMPINGS, Small
Olympic Tool & Mfg. Co., 37 Chambers St., New York 7, N. Y.
Walter Co., S., 144 Centre St., Brooklyn 31, N. Y.

724. MICROWAVE TRANSMISSION LINES and ACCESSORIES
Buggie & Co., H. H., Madison Ave. & 22nd St., Toledo 1, Ohio

726. FRACTIONAL H.P. MOTORS
Alni Corp., 10 E. 52nd Street, New York 22, N. Y.

729. SERVO MOTORS
Transicoil Corp., 114 Worth St., New York, N. Y.

731. TIMING MOTORS
Cramer Co., R. W., Centerbrook, Conn.

751. PANELS
Langevin Co. Inc., The, 37 West 65th St., New York 23, N. Y.
Walter Co., S., 144 Centre Street, Brooklyn 31, N. Y.

754. FACSIMILE RECORDING PAPERS
The Western Union Telegraph Co., 60 Hudson St., New York 13, N. Y.

755. INDUSTRIAL PICKUPS
Rek-O-Kut Co., 146 Grand St., New York 13, N. Y.

758. TRANSCRIPTION and PHONOGRAPH PICKUPS
Rek-O-Kut Co., 146 Grand St., New York 13, N. Y.

761. PLUGS and JACKS
Buggie & Co., H. H., Madison Ave. & 22nd St., Toledo 1, Ohio

764. POSTS, BINDING
Fahnestock Electric Co. Inc., 46-44 Eleventh St., Long Island City 1, N. Y.

765. POWER SUPPLIES
Audio Products Co., 2101 W. Olive Ave., Burbank, Calif.
Electronic Associates Inc., 61 Brighton Ave., Long Branch, N. J.
Furst Electronics, 800 W. North Ave., Chicago 22, Illinois

766. ELECTRONICALLY REGULATED POWER SUPPLIES
Furst Electronics, 800 W. North Ave., Chicago 22, Illinois

768. VOLTAGE REGULATED POWER SUPPLIES
Furst Electronics, 800 W. North Ave., Chicago 22, Illinois

771. RACKS, RELAY
Audio Products Co., 2101 W. Olive Ave., Burbank, Calif.

777. VOLTAGE REGULATORS and STABILIZERS
Audio Products Co., 2101 W. Olive Ave., Burbank, Calif.
Furst Electronics, 800 W. North Ave., Chicago 22, Illinois

785. GENERAL PURPOSE RELAYS
Adams & Westlake, Michigan St., Elkhart, Indiana

787. INDUSTRIAL CONTROL RELAYS
Adams & Westlake, Michigan St., Elkhart, Indiana

789. KEYING and BREAK-IN RELAYS
Buggie & Co., H. H., Madison Ave. & 22nd St., Toledo 1, Ohio

802. SNAP ACTION RELAYS
Adams & Westlake, Michigan St., Elkhart, Indiana

804. TELEPHONE RELAYS
Adams & Westlake, Michigan St., Elkhart, Indiana

806. TIME DELAY RELAYS
Electronic Associates Inc., 61 Brighton Ave., Long Branch, N. J.

807. TRANSFER RELAYS
Adams & Westlake, Michigan St., Elkhart, Indiana

817. POTENTIOMETERS and RHEOSTATS
Electronic Associates Inc., 61 Brighton Ave., Long Branch, N. J.

818. WIRE WOUND RESISTORS
Audio Products Co., 2101 W. Olive Ave., Burbank, Calif.

829. HERMETIC SEALS
Buggie & Co., H. H., Madison Ave. & 22nd St., Toledo 1, Ohio
Hermetic Seal Products Co., 414 Morris Ave., Newark 3, N. J.

849. SOLENOIDS
Alni Corp., 10 E. 52nd St., New York 22, N. Y.

852. SPRINGS
Instrument Specialties Co. Inc., 254 Bergen Blvd., Little Falls, N. J.

PRODUCTS INCORRECTLY LISTED

The following firms have advised us that the products which are listed below are not manufactured by them.

230. STROBOSCOPES
Audio Products Co., 2101 W. Olive Ave., Burbank, Calif.

308. A.F. SIGNAL GENERATORS
Measurements Corp., Boonton, N. J.

463. BELLOWS
Technographics Inc., 1457 W. Diversity Blvd., Chicago 14, Ill.

551. RADIO REMOTE CONTROLS
Langevin Co. Inc., The, 37 West 65th St., New York 23, N. Y.

774. TUBE RECTIFYING UNITS
Electrons Inc., 127 Sussex Ave., Newark, N. J.

912. RF and IF TRANSFORMERS
Airdesign Inc., 241 Fairfield Ave., Upper Darby, Pa.

NAME and ADDRESS CORRECTION or CHANGE

Biddle Co., Jas. G., 1316 Arch St., Philadelphia 7, Pa.
Communication Products Co. Inc., Keyport, N. J.
Fairchild Camera & Instrument Corp., 88-06 Van Wyck Blvd., Jamaica 1, N. Y.
Franklin Airloop Corp., 43-20 34th St., Long Island City, N. Y.
Franklin Mfg. Corp., A. W., 43-20 34th St., Long Island City, N. Y.
Gulow Corp., 62 William St., New York 5, N. Y.
Hardwick, Hindle Inc., 40 Hermon St., Newark, N. J.
Instrument Resistors Co., 1036 Commerce Ave., Union, N. J.
Kay Electric Co., 47 North Grove St., East Orange, N. J.
King Laboratories, Inc., 127 Solar St., Syracuse 4, N. Y.
Robinson Aviation Inc., Teterboro Air Terminal, Teterboro, N. J.
Schweitzer Paper Co., 182 Cornelison Ave., Jersey City, N. J.
Trefz Mfg. Co., 511 East 164th St., New York 56, N. Y.
United States Television Mfg. Corp., 3 West 61st St., New York 23, N. Y.
Weltronic Co., 19500 West 8 Mile Rd., Detroit 19, Mich.
Westinghouse Electric Corp., Electronic Tube Sales Dept., Bloomfield, N. J.
White Dental Mfg. Co., S. S., Industrial Div., 10 E. 40th St., New York 16, N. Y.

ADDITIONAL CORRECTIONS WILL APPEAR IN THE DECEMBER ISSUE

Metal Tubing in Glass Houses

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The Superior Tube Company, Electronics Division, has spared nothing in its effort to bring to the Radio Tube Industry, through its highly specialized facilities, metal tubing in the form of cathodes, anode and grid cylinders, and all types of fabricated tubular parts. These products, used in all types of electron tubes, are the metallurgical and physical counterparts of your electronic expectations. • Material control standards, otherwise unattainable, are now realities. Superior's Electronics Laboratory has made possible far-reaching research and development of electronic tubing, through the study of materials, processes and controls. • Whatever your requirements in metal tubing for electron tubes, bring your problems to us. The Engineering Staff of Superior Electronics Division will welcome your inquiries and the privilege of working with you.

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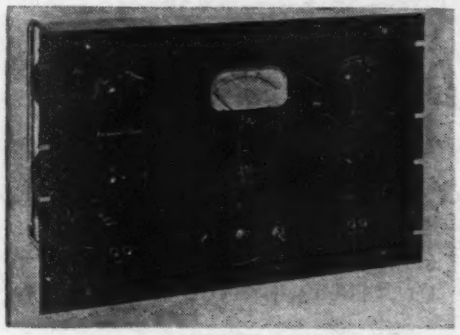
NEW PRODUCTS

Edited by A. A. McKENZIE

New apparatus, packaged units, and component parts are described. Services, catalogs, and manufacturers' publications are reviewed

Noise Suppressor (1)

TECHNOLOGY INSTRUMENT CORP., 1058 Main St., Waltham 54, Mass. The new type 910-A Dynamic Noise Suppressor has been particularly designed for broadcast station use. It allows the playing of shellac and vinyl recordings, subject to the limits of their dynamic range, on the same program with high-quality transcriptions without the unfavorable comparison occasioned by the usual high background noise. An instantaneous gate circuit operates to let through musical passages with practically no impairment, but substantially eliminates noise. The equipment can also be used for such purposes as the presentation of shortwave rebroadcasts in which noise is often the limiting factor. Engineered for broadcast use, the equipment illustrated is arranged



for quick operation or removal and standard monitoring procedures. Maximum suppression of high-frequency noise is 20 db and for low-frequency noise, 15 db.

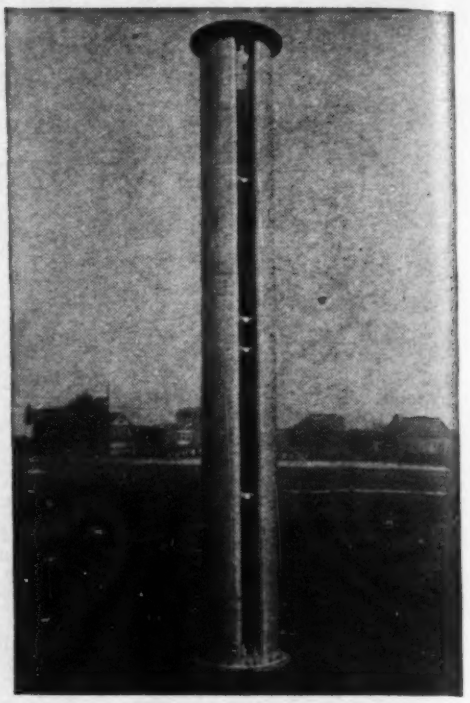
Television Tube (2)

ZETKA LABORATORIES, INC., 131 Getty Ave., Clifton, N. J. The type Z-15DP4 television tube has a black and white screen 15 inches in diameter. Focus and deflection are magnetic. A feature of the new tube is its short overall length (about 20 inches). The face plate is substantially flat to provide a large useful screen surface. Typical operation

includes anode voltage of 8,000 to 10,000 volts; grid no. 2, 250 volts; grid no. 1, minus 45 volts; and focusing coil current between 88 and 116 milliamperes.

F-M Antenna (3)

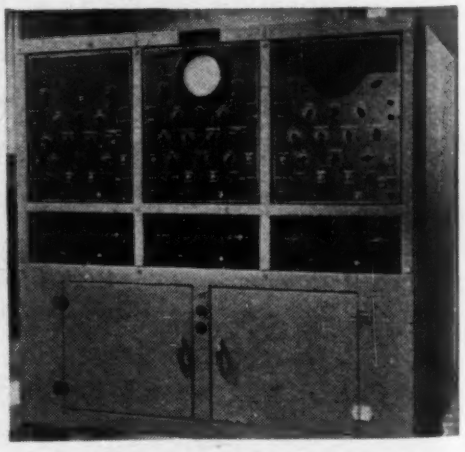
RADIO CORP. OF AMERICA, Camden, N. J. The Pylon antenna is a single-element f-m radiator that is self-supporting. When additional gain is desired, one unit can be stacked upon another and an additional feed run from element to element inside the tube that forms the antenna. A stack of four sections results in a power gain of six over a simple dipole. The same antenna structure operates over the whole f-m band (88-108 megacycles) and will handle maximum power granted to f-m stations. Each pylon



is 13 feet high, with a diameter of 19 inches, and weighs 350 pounds. Each end is provided with a flange for mounting on a base, display of a beacon at the top, or addition of another element. Radiation is horizontally polarized.

Tri-Channel Oscilloscope (4)

ELECTRONIC TUBE CORP., 1200 East Mermaid Ave., Chestnut Hill, Philadelphia 18, Pa. The E-3G47-S1 triple-channel oscilloscope comprises three separate channels operating into a type 5Z3P11 triple-gun cathode-ray tube. The equipment has been designed for encephalographic studies and is equipped with a General Radio 35-mm oscillograph recorder capable of film speeds between 5 and 35 feet a second. The tube has a low-persistence actinic blue screen. Vertical



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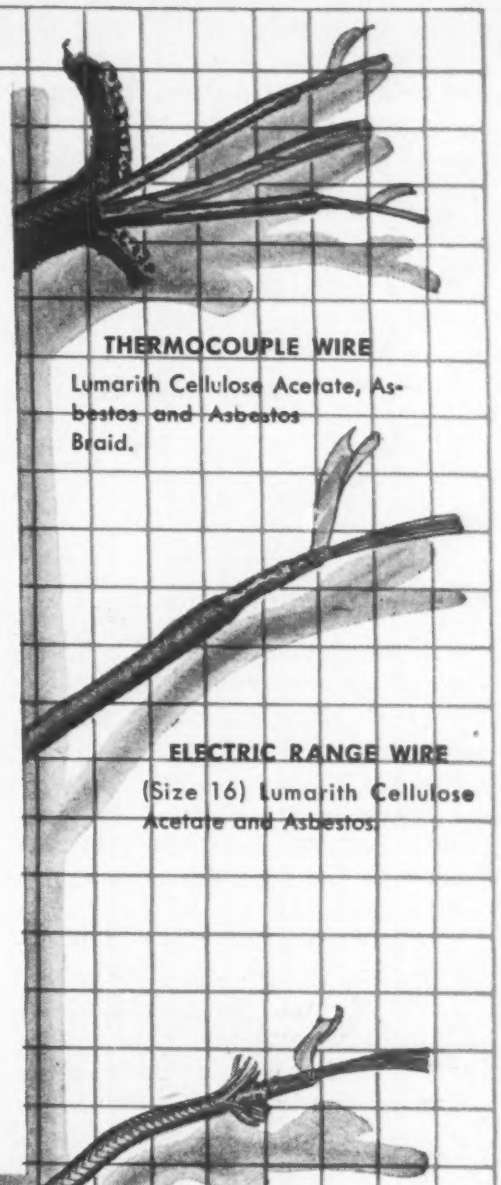

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ELECTRIC RANGE WIRE
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AIRCRAFT WIRE
Asbestos, Lumarith Cellulose Acetate, Asbestos, Glass Braid and Silicone finish.

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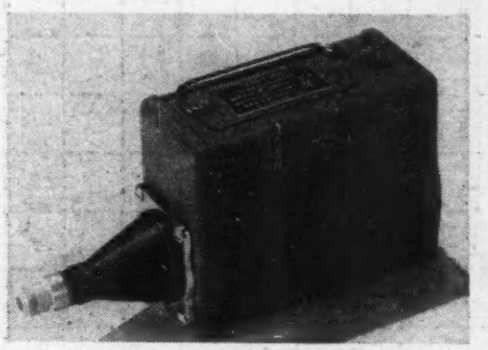
amplifiers have a uniform frequency response from 2 cycles to 100 kilocycles and the horizontal amplifiers have a uniform response from 1 cycle to 30 kilocycles. Each of the three channels is equipped with a marker generator, and various switching and interconnection means are provided to make the use of the equipment as flexible as possible.

Coaxial Termination (5)

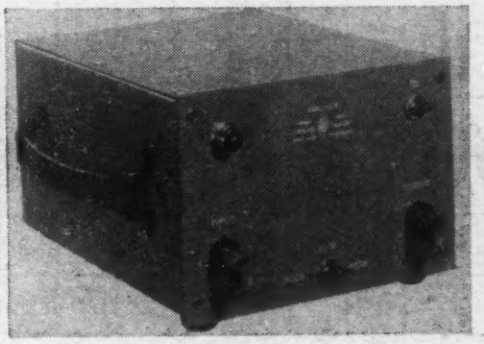
BIRD ELECTRONIC CORP., 1800 East 38th St., Cleveland 14, Ohio. The Termaline Model 81 coaxial resistor is designed to dissipate up to 50 watts of r-f power with a low voltage standing wave ratio. It consists essentially of a coaxial resistor immersed in a liquid coolant. It can be used as an impedance stand-



ard, non-reactive termination, dummy antenna and for the measurement of standing wave ratios.

Wide-Band Amplifier (6)

HEWLETT-PACKARD CO., Palo Alto, Calif. The type 450A amplifier has been designed for general purpose or laboratory use with frequency response flat within 0.5 db between



10 and 1,000,000 cycles. Input impedance is 1 megohm shunted by 15 micromicrofarads. The equipment is stable at a gain of 20 or 40 db.

Low-Frequency Q-Meter (7)

FREED TRANSFORMER CO., INC., 72 Spring St., New York, N. Y. The No. 1030 Q-meter contains an audio-frequency oscillator, precision tuning capacitor, power amplifier and two vacuum-tube voltmeters. Oscillator frequency range is continu-

ously variable from 50 cycles to 50,000 cycles in four ranges. Accuracy of the Q measurement is approximately 6 percent.

Permeability Tuners (8)

ELECTRONIC LABORATORIES, INC., Indianapolis, Ind. The E-L Vario-Tuner is a new permeability-type broadcast tuner consisting of r-f and oscillator sections covering the frequency range 540 to 1,620 kilocycles. The unit is manufactured particularly for experimenters and schools desiring to build a 6-tube receiver.

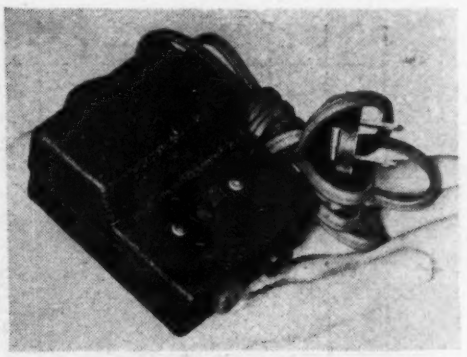
Medium-Power Speaker (9)

ALTEC LANSING CORP., 250 West 57th St., New York 19, N. Y. The model 600 Dia-Cone speaker is an-

other in the line of dual speakers designed for good fidelity in home reception and reproduction. This model has a power rating of 18 watts and a 3-inch voice coil with an impedance of 10 ohms. Weight of the unit is 12 pounds.

Circuit Tester (10)

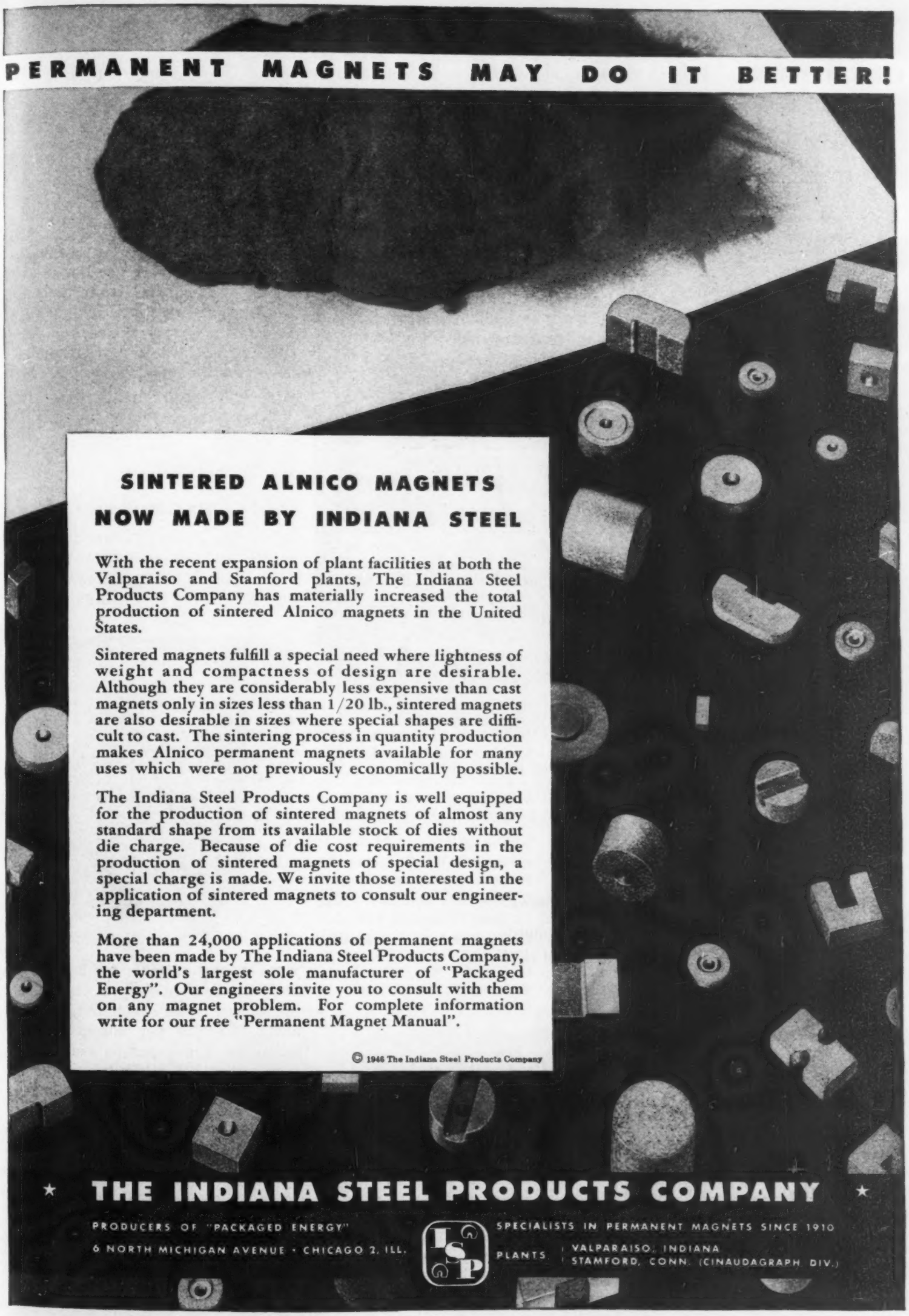
ROBSON-BURGESS CO., Omaha, Neb. The Meg-Lite is essentially a continuity tester consisting of a 115-



volt a-c or d-c line, a neon lamp, series resistor and switch, and a pair of leads. It is conveniently packaged for continuity testing and sells for about $5.

Air-Cooled Amplifier (11)

GENERAL ELECTRIC CO., Syracuse, N. Y. The type GL-5518 air-cooled transmitting tube has been designed for use in grounded-grid circuits. A pair of the tubes in an experimental transmitter operating at 108 megacycles showed a useful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The Indiana Steel Products Company is well equipped for the production of sintered magnets of almost any standard shape from its available stock of dies without die charge. Because of die cost requirements in the production of sintered magnets of special design, a special charge is made. We invite those interested in the application of sintered magnets to consult our engineering department.
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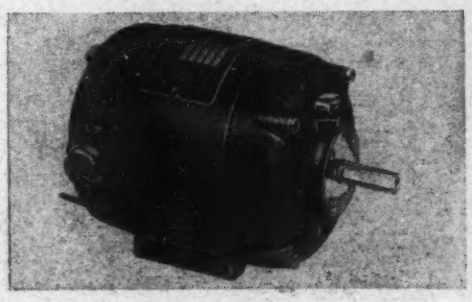
output of 12.9 kilowatts with a d-c plate voltage of 6,000 volts. Full ratings apply up to 110 megacycles. In typical operation, driving power per tube is 1,400 watts.

High-Speed Motor (12)

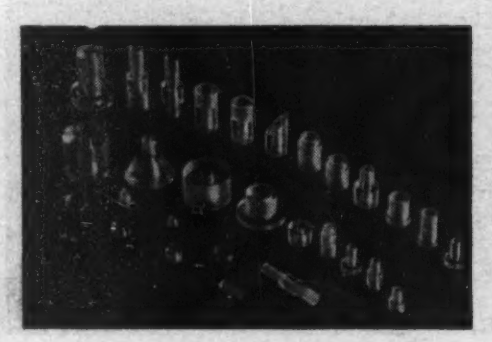
JOHN OSTER MFG. CO., Racine, Wis. The type EU-450 series-wound motor operates with a speed of 4,000 to 8,000 rpm at a power of



1/15 hp. Utilizing either a-c or d-c, the motor can be used for a tube-cooling blower or in similar applications.

New Plastic (13)

GENERAL ELECTRIC CO., Pittsfield, Mass. A new plastic material known as Textolite 1422 possesses a



low power factor and machines readily, making it suitable for coil forms and insulators used at ultra-high frequencies.

Electronic Timer (14)

GENERAL CONTROL CO., 1200 Soldiers Field Road, Boston 34, Mass. Promatic timers provide full automatic or semiautomatic control of industrial or radio equipment. Used

in pairs or combinations they can control a number of operations in a predetermined sequence with either self or manual recycling. Five timing periods, depending upon the value of fixed capacitor plugged into the circuit, are available from ½ to 60 seconds. The unit can also be modified for use as a sensitive control relay.

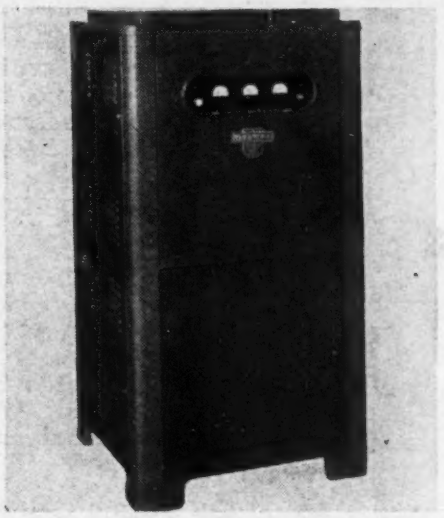
Plug-In Amplifier (15)

RADIO CORP. OF AMERICA, Camden, N. J. A new line of plug-in amplifiers is now in production for broadcast station use. With this system, a whole amplifier assembly can be demounted and replaced by another as is done with a tube. The BR-2A shelf assembly mounts in a standard rack. At the rear of the shelf are rectangular socket assemblies into which contactor prongs fit

when the amplifier unit is locked into place by one or two levers. A family of amplifiers used in various broadcast station functions is available in the proper dimensions for the new mounting. Six preamplifier chassis units, for instance, fit on a single shelf.

Dual Electronic Heater (16)

INDUCTION HEATING CORP., 389 Lafayette St., New York 3, N. Y. The Ther-Monic M-285C electronic heating generator is a single dual-



purpose unit suitable for both induction and dielectric heating operations. Full load output is about 285 Btu per minute or 5 kilowatts. The induction generator operates on 375 kilocycles and the dielectric on 20 megacycles. Changeover from one method to another merely involves replacing one radio-frequency unit with the other.

Transmitting Triode (17)

GENERAL ELECTRIC CO., Syracuse, N. Y. The type GL-5C24 triode has

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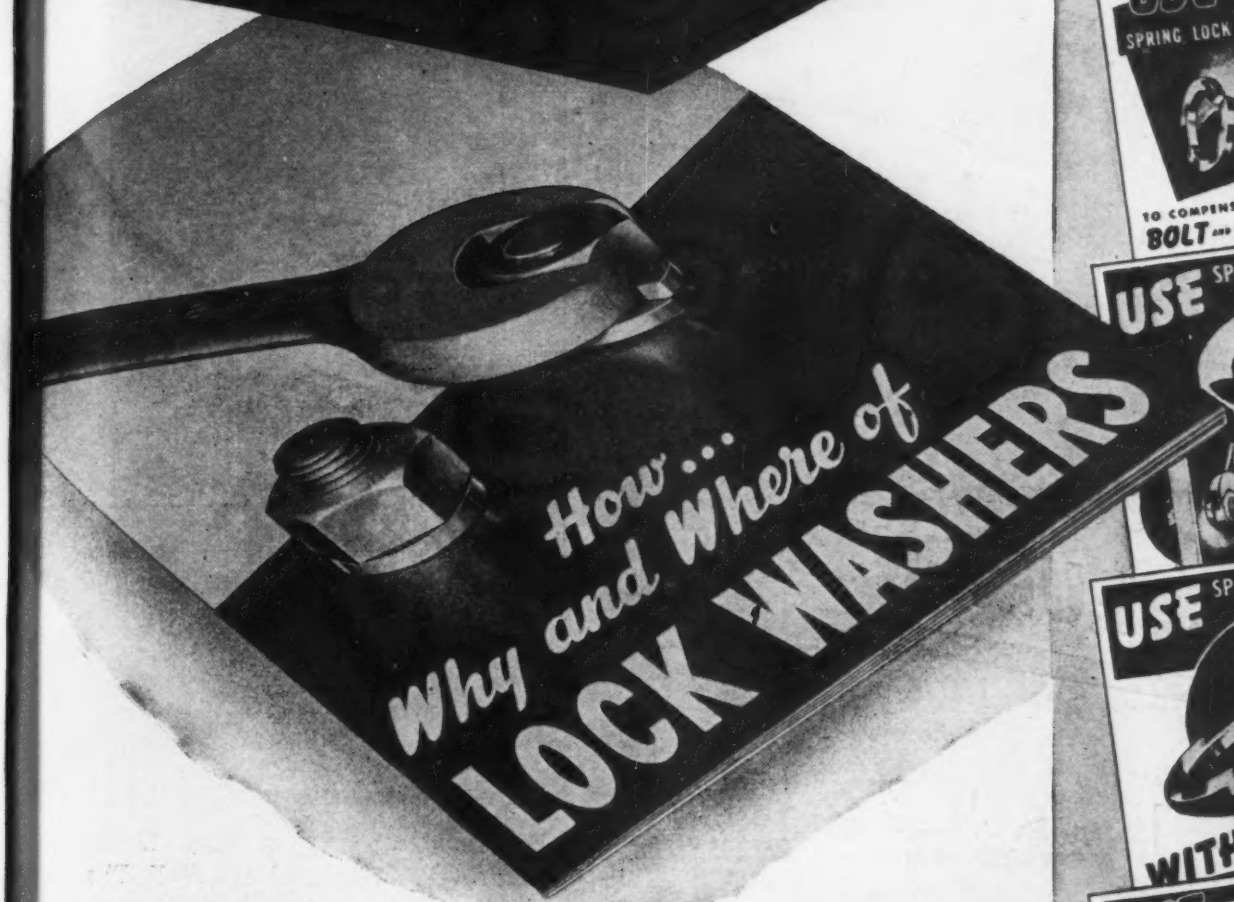

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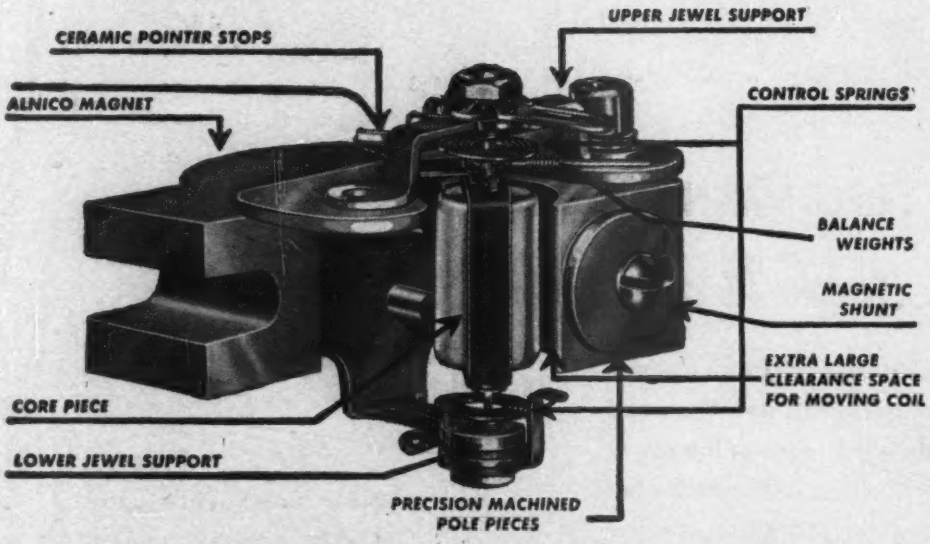

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7. MAGNETIC SHUNT is standard equipment on each DC instrument, insuring uniform damping characteristics.

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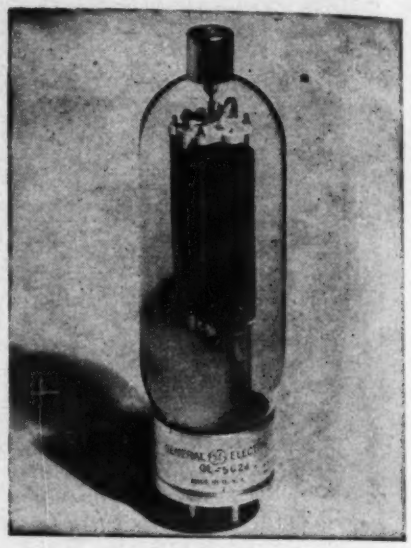
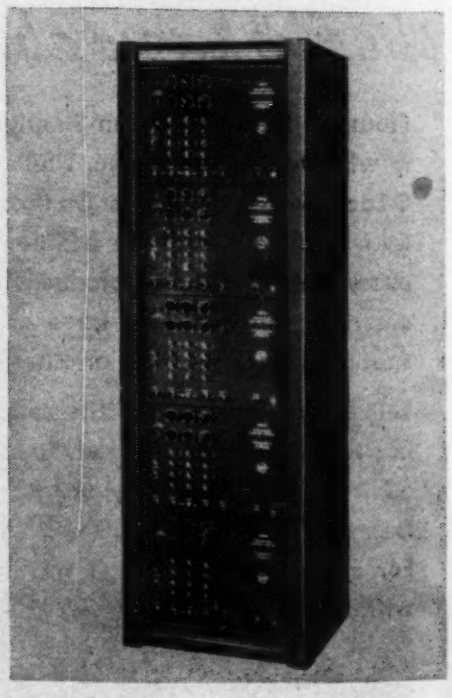
been designed primarily as a class A and class AB_1 audio-frequency amplifier and modulator. Typical potentials encountered in using the



tube as a class A amplifier are: d-c plate, 1,500 volts; peak a-f grid, 150 volts; power output, 55 watts.

Multiple Counter (18)

POTTER INSTRUMENT CO., 136-56 Roosevelt Ave., Flushing, N. Y. The Model 69-3 multiple counter consists of five dual counters in combi-



nation so that rates as high as 12,000 a minute may be determined. Such a device can be used for counting radiation particles, small

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LINDE Nitrogen is 99.7% pure, but is also available bone dry and at higher purity for special applications. It is supplied as a compressed gas in cylinders containing 224 cu. ft. each, or in bulk in tank-truck and tank-car lots as a liquid which is converted into gaseous nitrogen as required. LINDE Nitrogen in bulk offers remarkable savings in cost and eliminates cylinder handling.

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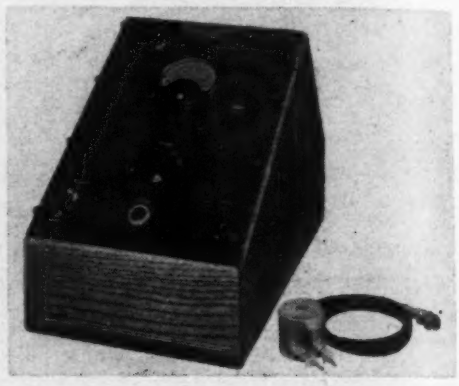
XENON — *Prest-O-Lite* ACETYLENE

articles like pills and buttons or the totalizing of variable quantities from several independent channels.

Tube Voltmeter (19)

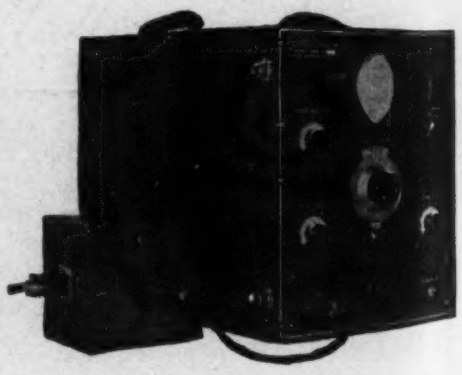
TELEVISO PRODUCTS CO., 7466 Irving Park Road, Chicago 34, Ill. The Series 200A vacuum-tube voltmeter uses a 0.5-volt full scale meter that allows accurate readings as low as 100,000 microvolts. The input tube is a plate circuit rectifier type that

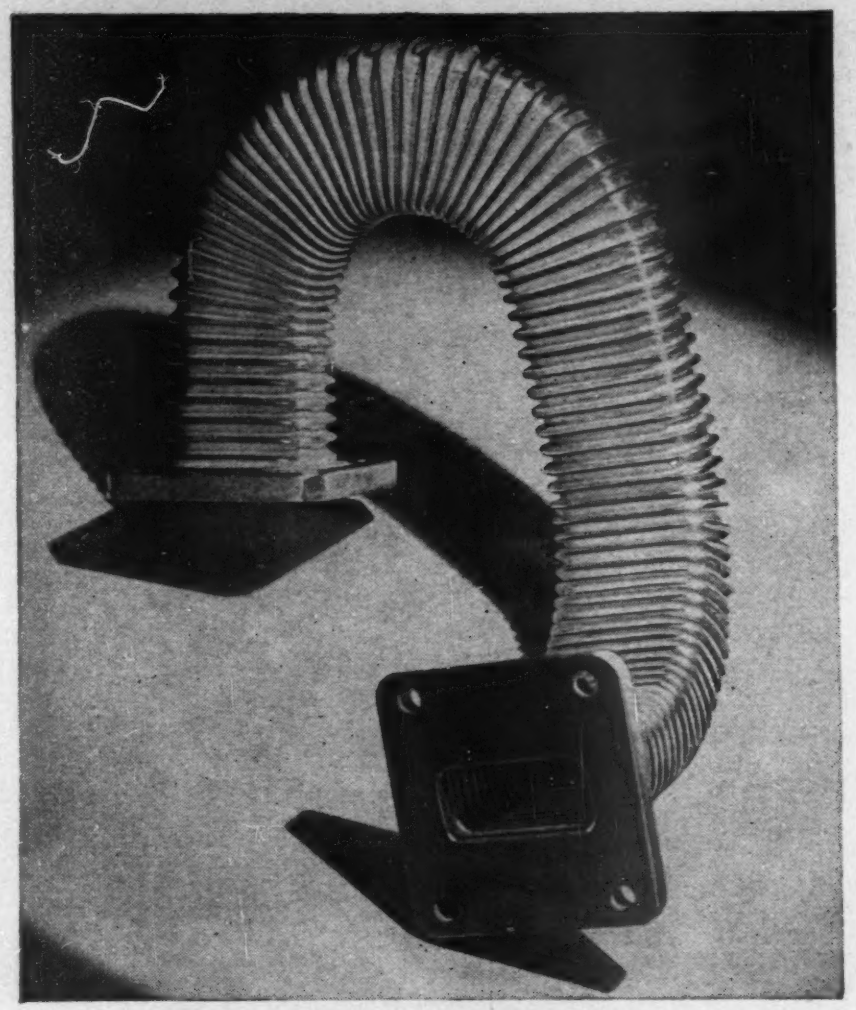


indicates rms values, rather than the usual diode type whose input admittance varies with frequency. Careful voltage regulation makes the circuit feasible. In addition, a source of 5 volts rms plus or minus 2 percent is furnished for calibration.

Ferromagnetic Analyzer (20)

ALLEN B. DU MONT LABORATORIES, Inc., Passaic, N. J. The Ferrograph provides a simple means for relatively unskilled personnel to identify or compare ferrous materials at a rapid rate. The basic principle of operation is the harmonic analysis of the induced voltage in the secondary of a test transformer in which the sample





This *Flexible* Tubing makes Radio Waves TURN CORNERS...

THIS AMERICAN Seamless Flexible Wave Guide is made from thin-wall rectangular metallic tube... can be extended, compressed or bent in two planes to small radii and withstands a large number of flexures of moderate amplitude.

Other widely used American Flexible Wave Guides are the "Vertebra" type, consisting of a series of choke-plate wafers inserted in a synthetic rubber jacket, and the "Moldlock" type, made of spirally wound strip with fully interlocked joints, with (or without) a synthetic jacket.

These high precision units mate electrically and mechanically with the standard sizes of rigid guide for operation at wave lengths from 20 to less than 3 Cm.

We will be glad to assist in selecting the wave guide best suited to the specific requirements of your installation. Write for our "Electronics Data Book."

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American Metal Hose Branch

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Impromptu Discussions about Miniature Tubes

"It's a fact, John, those little TUNG-SOL Miniatures are actually doing a better job than the big tubes. Take radio frequency amplifiers for example. There's the TUNG-SOL 6BA6 for transformer and storage battery operated sets and the 12BA6 for series filament operation. It's only natural that you get greater rigidity with the shorter structure and the same grid cathode spacing . . . and to give you some idea of space saving, one of these little fellows occupies less than half the chassis area that a big tube requires. Think what this means in compact equipment like an auto set.

"With these miniature amplifiers it's possible to obtain the correct bias by means of a cathode resistor of 68 ohms for normal operating current. If unbypassed this gives partial compensation for variations in input capacitance due to changes in automatic volume control voltage. Almost complete compensation can be obtained with a 100 ohm unbypassed cathode resistor. Under this condition the effective transconductance is 2700 microhms. Excellent performance is obtained in the frequency modulation and television intermediate frequency bands. The stable gain figure of merit is about the same as for the large type tube while the broad band figure of merit is about 30% greater.

"I tell you, John, you should lay your tube problems before these TUNG-SOL Engineers. They'll help you select the miniature that'll be most efficient and they won't disclose your plans to others. You see they're tube manufacturers, not set builders."

TUNG-SOL

vibration-tested

ELECTRON TUBES

TUNG-SOL LAMP WORKS INC., NEWARK 4, NEW JERSEY

Sales Offices: Atlanta • Chicago • Dallas • Denver • Detroit • Los Angeles • New York

Also Manufacturers of Miniature Incandescent Lamps, All-Glass Sealed Beam Headlight Lamps and Current Intermittors

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Contains Latest Available Information on

TIMING MOTORS

Engineers, designers—send for your *free* copy of this valuable new guide, today. HAYDON'S 1947 Catalog is a storehouse of information and specifications of timing motors for every conceivable application. And it's all been revised—many new items! Every motor pictured . . . complete operational data and blueprint sketches shown . . . informative section on new special and optional features. Up-to-date items include AC timing motors and gear units, shift units, brake units, friction units, elapsed time indicators, fixed interval repeat cycle timers, fixed interval automatic reset timers and many others. Made in handy 8½" x 11" size to fit your files conveniently. Be sure to add this late edition to your files.

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Name .....

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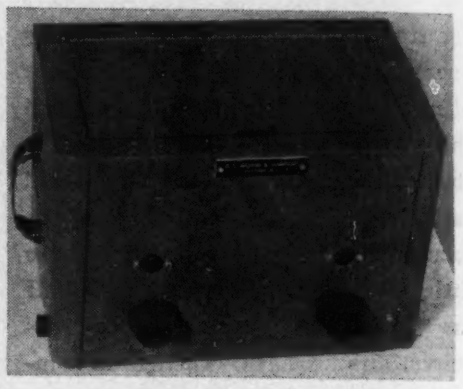
City ..... Zone..... State .....

is made the core. Amplitude and phase angles of the fundamental and third harmonic components are usually sufficient indication for identification. A cathode-ray tube is used for direct display of the phenomena. The complete testing equipment weighs 115 pounds.

Strain Gage Amplifier (21)

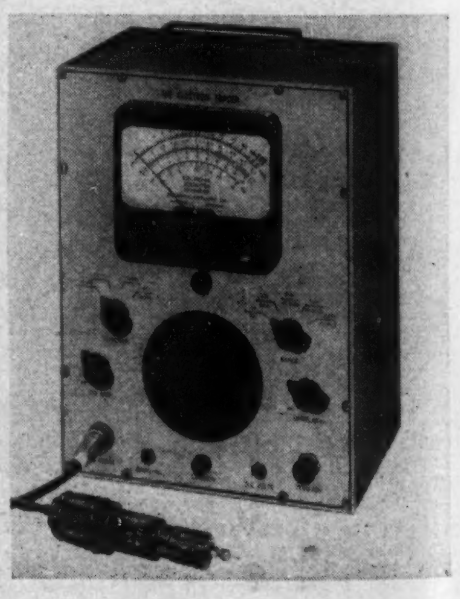
G. C. WILSON & Co., 2 N. Passaic Ave., Chatham, N. J. A new amplifier designed for vibration studies



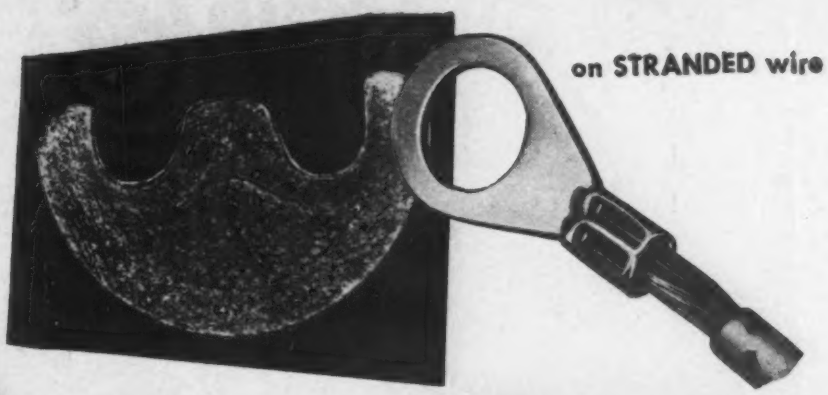
provides amplification of 25,000 between 1 and 30 cycles. Designed to couple directly to the plates of a cathode-ray oscilloscope, the unit includes its own regulated power supply.

Audible Signal Tracer (22)

ELECTRONIC INSTRUMENT Co., Inc., 926 Clarkson Ave., Brooklyn 3, N. Y. The Model 113 Electron Tracer



on SOLID wire



on STRANDED wire

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IRREGULAR SHAPED CONDUCTORS

The new AMP SOLISTRAND terminal—originally designed for solid wire—assures a superior connection for ALL types of conductors . . . terminal makes full surface area contact with the conductor.

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AIRCRAFT-MARINE PRODUCTS Inc.

1521-53 NORTH FOURTH STREET. HARRISBURG. PA.

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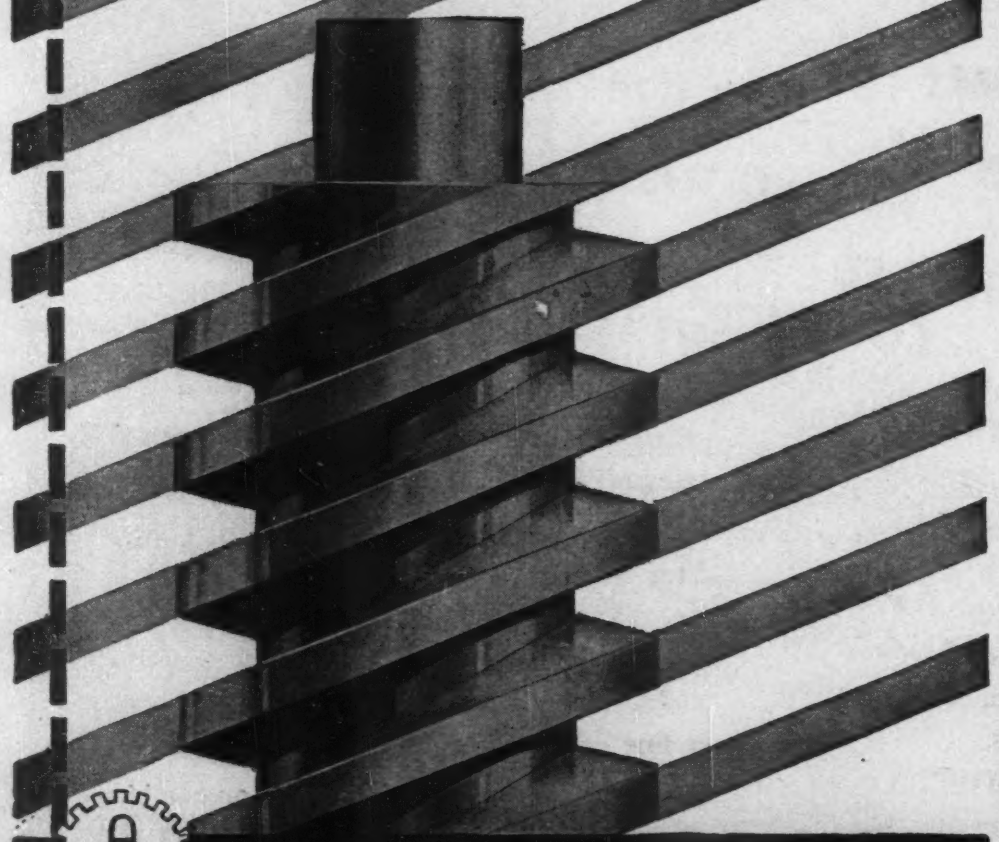
QUAKER CITY CRAFTSMEN, USING THE MOST MODERN MACHINES PRODUCE PRECISION GROUND FORM WORMS . . . OUR RIGID STANDARDS ARE NOW MEETING EXACTING DEMANDS OF THE ELECTRONICS INDUSTRY . . . YOUR INQUIRY WILL BE APPRECIATED AND WILL BE GIVEN PROMPT ATTENTION.

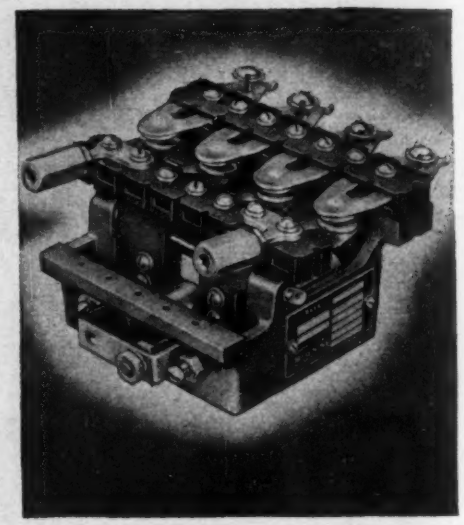


QUAKER CITY GEAR WORKS, INC.
1918 NORTH FRONT ST.
PHILADELPHIA 22, PENNA.

is a complete electronic volt-ohmmeter operating from socket power. It is also equipped with an audio amplifier and loudspeaker for audible signal tracing through the various stages of a receiver.

Heavy-Duty Relay (23)

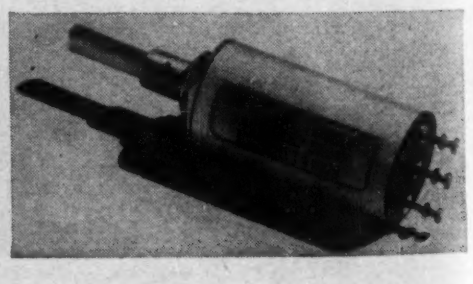
SIGNAL ENGINEERING & MFG. CO., 154 West 14th St., New York 11, N. Y. A new heavy-duty relay with double-pole, single-throw contacts will break 50 amperes at 115 volts a-c or 24 volts d-c. A double-break

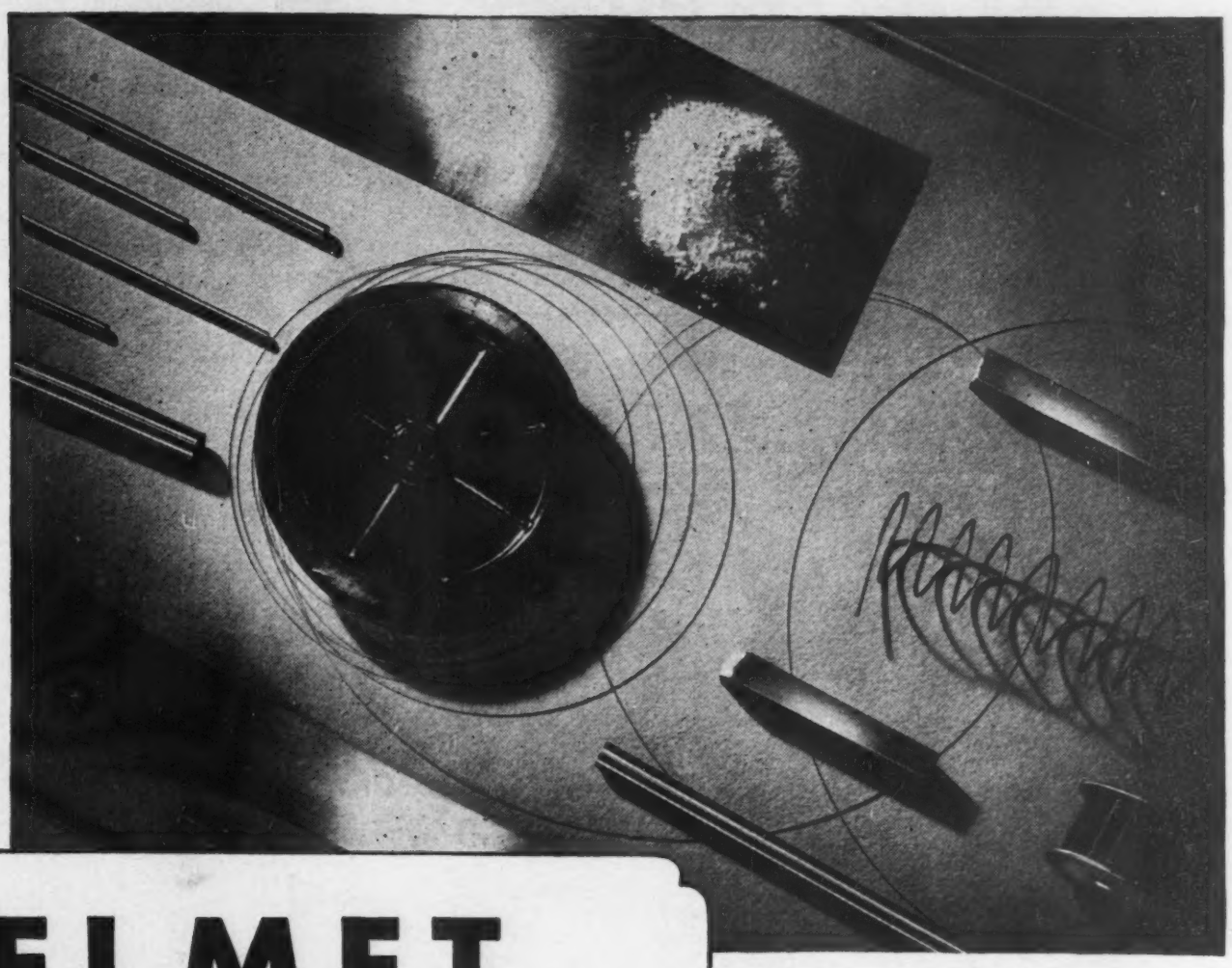


feature of the contact mechanism eliminates pigtail connections. Coils can be supplied to operate at voltages up to 230 volts, a-c or d-c. Typical power consumption of the coils is less than 3.5 watts on d-c, 8 watts on a-c.

Helical Potentiometer (24)

VAN DYKE INSTRUMENTS, P. O. Box 696, Tarzana, Calif. The small size and weight of a new helical potentiometer make it useful for aircraft instrumentation and electronic cal-





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Every one of the tungsten and molybdenum products supplied by North American Philips is backed by the knowledge of processes and techniques developed by an organization with a background of over half a century in the electrical field. Every piece of material is controlled to your most rigid specifications.

We can supply you with most of the tungsten and molybdenum products you need—in rod, bar, wire, sheet or powder form.

When you want tungsten or molybdenum—write, wire or telephone North American Philips. And remember, the services of our application engineers are always at your disposal, their years of specialized experience are yours on call.

Products of North American Philips include: other fine wires, diamond dies, quartz oscillator plates, radio and television components, cathode ray tubes, industrial and medical x-ray equipment, tubes and accessories.

NORTH AMERICAN PHILIPS COMPANY, INC.

Dept. S-11, 100 East 42nd Street, New York 17, N. Y.

FOR SALE

PLANCOR 2189

PUNXSUTAWNEY, PENNA.

This plancor was erected in 1944 for producing cylindrical carbon electrodes (up to size ½") used in the construction of dry cell batteries.

It is reasonable to believe that this plant represents the most modern of its type, and could be a low unit cost producer of electrodes with near capacity production. The output would vary between 45 and 60 million electrodes a month, depending upon their size.

With certain additions and changes in this facility, it is quite possible that other carbon products could be produced—such as brushes for motors, contacts for electrical switch gear, electronic tube anodes, carbon discs, molds for casting, etc.

This plancor consists of land, building, machinery and equipment briefly described as follows:

LAND: Approximately 10½ acres.

BUILDINGS: *Finishing Building*—122' x 233'. One story. Structural steel framing. Sidewalls of concrete block and continuous steel sash. Precast gypsum roof slabs, built-up roofing. Area 28,600 sq. ft.

Furnace Building—12' x 233'. One story, with two supported floors at one end. Structural steel framing. Corrugated siding with continuous sidewall sash. Corrugated asbestos roof. Freight elevator to supported floors. Total area 34,060 sq. ft.

Boiler House—40' x 40'. One story. Cinder block walls. Gypsum plank roof.

MACHINERY and EQUIPMENT: Production equipment, machine tools, laboratory and testing equipment, furniture and fixtures. These include carbon furnaces, grinders and accessories, extrusion presses, mixers, rotary dryers, cutting tables, etc.—drill presses, lathe, shaper, milling machine, etc.—micrometers, testing sieves, platinum crucible, etc.—lockers, office furniture, calculator, etc.

The furnace building has two, 3-ton girder cranes and there are four hoists—of 1, 2 and 3½ ton capacities.

Complete utilities, including natural gas, are supplied by local companies. There are sidings from the B & O R. R. on the site. And the community provides an excellent labor market.

CREDIT TERMS for the purchase of this property may be arranged. And if you can qualify as a small business concern you may obtain *high priority* for its purchase through the Reconstruction Finance Corporation.

Information contained herein is not intended for use as a basis for negotiation. The War Assets Administration reserves the right to reject any or all proposals.

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For detailed information about this offering of Government-owned surplus property, address:

WAR ASSETS ADMINISTRATION

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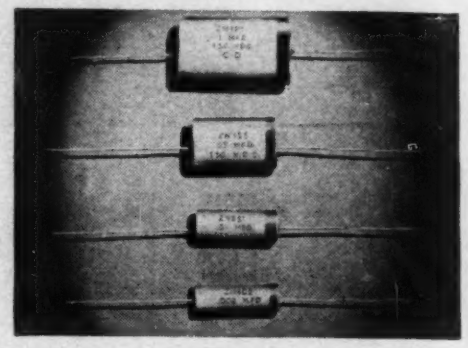
Cleveland, Ohio 742

culators where space is at a premium. Five- and ten-turn units are available from stock, but other special types are available on order. The diameter of the potentiometer is 1 inch, the length varying with number of turns but usually not exceeding about 3¾ inches.

Flat Midget Capacitors (25)

CORNELL-DUBILIER ELECTRIC Corp., South Plainfield, N. J. A new line of flat midget capacitors, type ZN, is now available for pocket radio, hearing aid or similar use. The units are noninductively wound



with Kraft paper and impregnated. Leads are securely anchored and the end-fill compound is not melted by a hot soldering iron. Capacitance values range from 0.001 to 0.1 microfarad in d-c rated voltages from 150 to 600 volts.

Gas-Free Metals (26)

NATIONAL RESEARCH CORP., 100 Brookline Ave., Boston 15, Mass. Quantities of gas-free metals in melts up to several hundred pounds are now available for high-vacuum work and allied techniques. A partial list of metals already used in the field of vacuum metallurgy includes copper, nickel, iron, chromium, manganese and lithium.

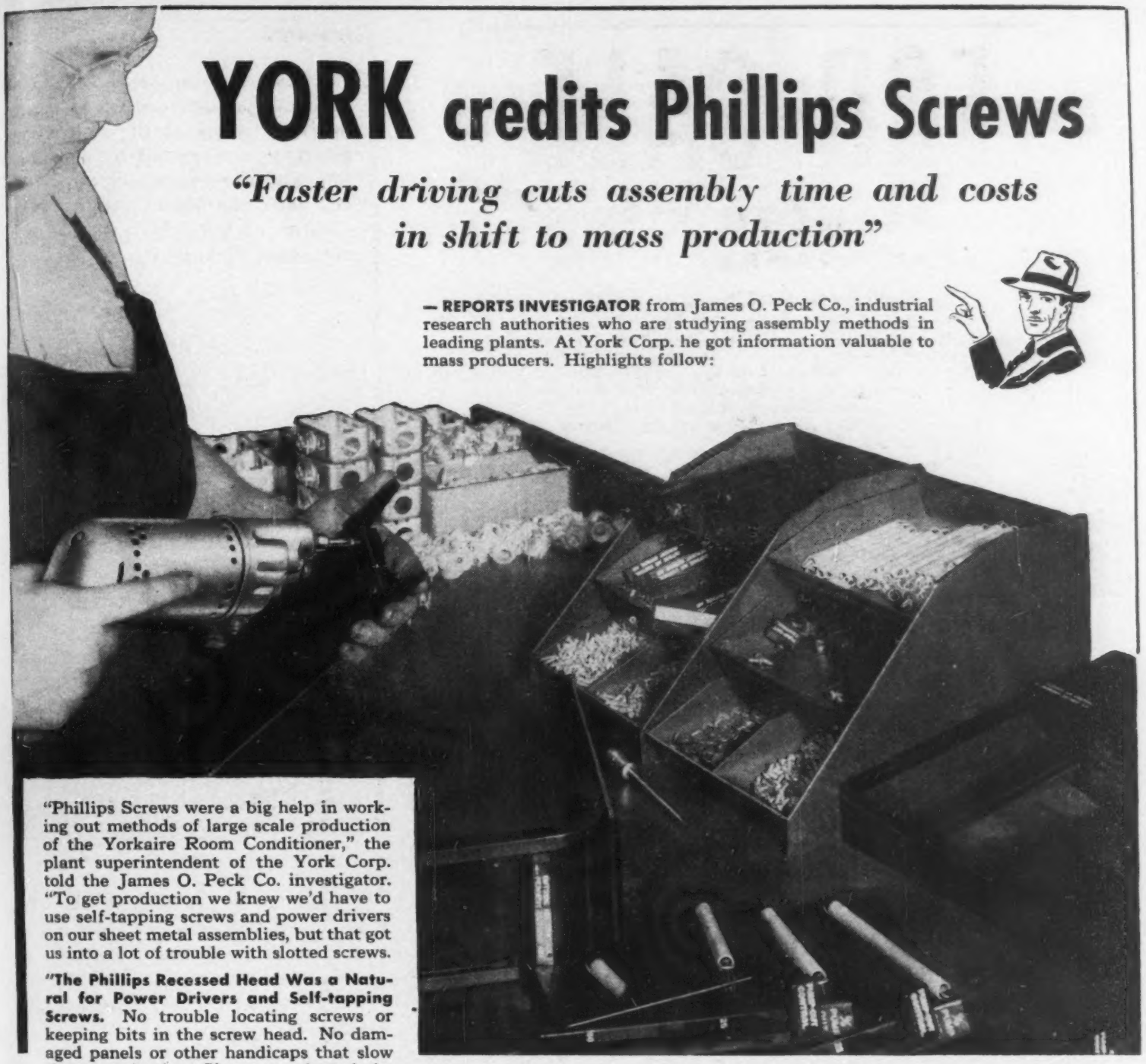
Flash Tube (27)

HYTRON RADIO AND ELECTRONICS CORP., Salem, Mass. The HD72 flash tube operates from the discharge

YORK credits Phillips Screws

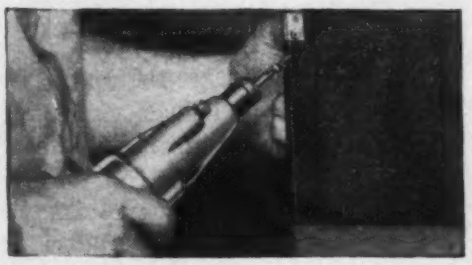
"Faster driving cuts assembly time and costs in shift to mass production"

— **REPORTS INVESTIGATOR** from James O. Peck Co., industrial research authorities who are studying assembly methods in leading plants. At York Corp. he got information valuable to mass producers. Highlights follow:



"Phillips Screws were a big help in working out methods of large scale production of the Yorkaire Room Conditioner," the plant superintendent of the York Corp. told the James O. Peck Co. investigator. "To get production we knew we'd have to use self-tapping screws and power drivers on our sheet metal assemblies, but that got us into a lot of trouble with slotted screws.

"The Phillips Recessed Head Was a Natural for Power Drivers and Self-tapping Screws. No trouble locating screws or keeping bits in the screw head. No damaged panels or other handicaps that slow down production. Since we adopted the Phillips Head in '37 it's been standard on all sheet metal assemblies.



"One-Hand Driving Is Easy With the Phillips 'Engineered Fit'. The precision recess snugs right onto the bit of the power driver and sticks there, making it so easy for the operator to center the screw in the hole that he can hold the work with one hand and drive with the other.

"Eliminated the Tremendous Amount of Screw Driver Slippage. Panels were no longer chewed up, a stop was put to turned or burred screw heads and the whole assembly line speeded up the moment we changed from slotted to Phillips Screws."

Important Information for You is available in the unabridged report by this independent investigator of the York Corporation's experience with Phillips Screws. *Other reports,* covering assembly practises in 9 prominent plants making products of metal, wood and plastics, are yours for the asking... FREE! Use the coupon NOW.

PHILLIPS *Recessed Head* SCREWS

Wood Screws • Machine Screws • Self-tapping Screws • Stove Bolts

26 SOURCES

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Atlantic Screw Works
Atlas Bolt & Screw Co.
Central Screw Co.
Chandler Products Corp.
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Corbin Screw Div. of American Hdwe. Corp.
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International Screw Co.
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Manufacturers Screw Products
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National Lock Co.
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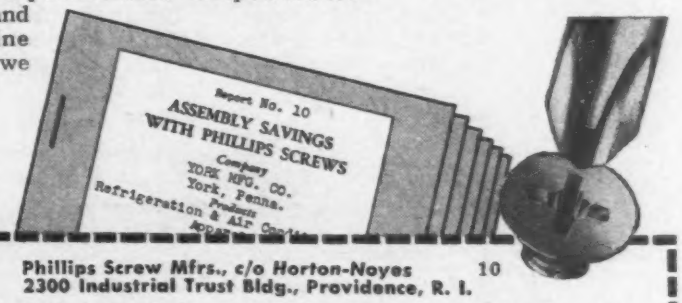
Parker-Kalon Corporation
Pawtucket Screw Co.
Pheoll Manufacturing Co.
Reading Screw Co.
Russell Burdsall & Ward Bolt & Nut Co.
Scovill Manufacturing Co.
Shakeproof Inc.
The Southington Hardware Mfg. Co.
The Steel Company of Canada, Ltd.
Sterling Bolt Co.
Wolverine Bolt Company



Phillips Screw Mfrs., c/o Horton-Noyes 10
2300 Industrial Trust Bldg., Providence, R. I.

Send me reports on Assembly Savings with Phillips Screws.

Name.....

Company.....

Address.....

.....

In Electronics there is no "good enough" but the best!

THE exacting requirements of the Radio and Electronic Industries demand solders and fluxes of the highest quality. Solder bonds must be dependable and permanent—especially where extreme changes in conditions occur, or in close assembly work.

The outstanding quality of Glaser Solders and Fluxes is the result of scientific research extending over more than two decades.

Glaser Plastic Rosin Core Solders are standard with leading manufacturers of capacitors, resistors, transformers, relays etc. To insure your product against short life and poor performance use Glaser Plastic Rosin Core Solder, the "Quality Solder" of time-proven dependability.

Let the experience of leading Electronic and Radio Technicians guide you in making Glaser Solders and Fluxes YOUR choice.

Glaser Rosin Core Solders exceed government specifications in purity, and are guaranteed to meet A.S.T.M. Class A specifications for solder.

Glaser
SOLDER PRODUCTS

GLASER PRODUCTS INCLUDE: Silver Brazing Solder and Flux; Fluxes for every purpose; Lead Products of Every Description; Lead Lining of acid and plating tanks.

Consult our Engineering Department on your Soldering and Flux problems.

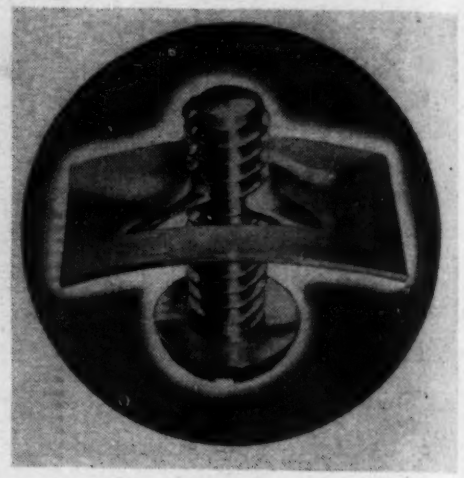
GLASER LEAD CO., INC.
31 Wyckoff Avenue Brooklyn 27, N. Y.

OUR 24th YEAR OF DEPENDABLE SERVICE TO AMERICAN INDUSTRIES

of a capacitor through a glass coil containing xenon gas. Anode potential can be varied between 5,000 and 3,000 volts. The flash exceeds 12 million peak lumens in intensity. The resultant light simulates that of the sun, making the device useful for color photography.

Speed Nut (28)

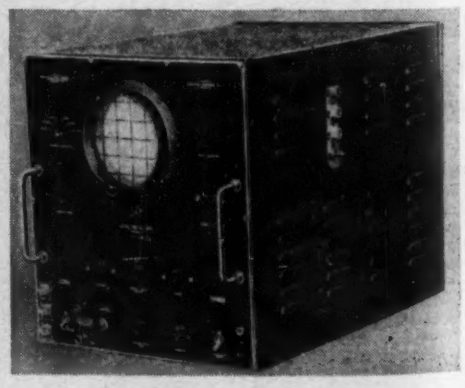
TINNERMAN PRODUCTS, INC., 2106 Fulton Road, Cleveland 13, Ohio. A new line of heat-treated spring steel



speed nuts is available in sizes to fit the ten most popular sheet metal and machine screws. The C7000 series take less room and cost less than the conventional threaded nut and lock washer.

Synchroscope (29)

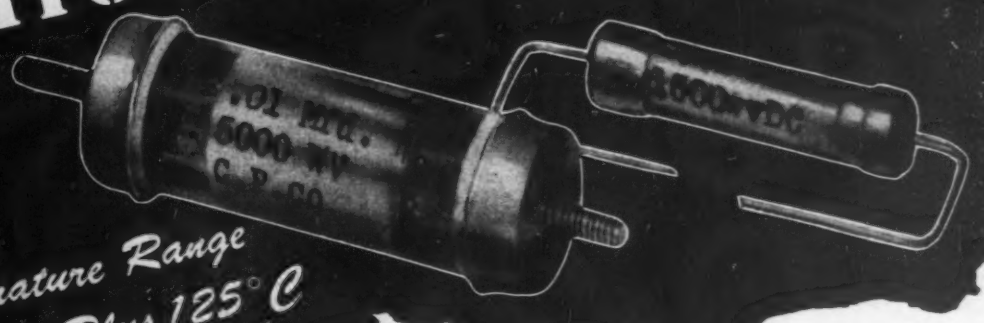
SYLVANIA ELECTRIC PRODUCTS, INC., 500 Fifth Ave., New York 18, N. Y. A synchroscope designed for the visual examination of the fine structure of periodic waveforms encountered in television, pulse time



PLASTICON* ASG Silicone-Filled GLASSMIKES

1-3/8 x 3-1/2

FOR HIGHER VOLTAGES



Extreme Temperature Range from Minus 60° C to Plus 125° C

From 600 to over 30,000 Volts

Modern functionally designed capacitors. Metal ferrules are soldered to silver bands fused to each end of heavy-walled glass tubes. This vacuum tight assembly is fungus-proof and passes Signal Corps, Air Corps and Navy thermal cycle and immersion tests.

Applications

- For low and medium power coupling and bypass circuits where mica capacitors have previously been required
- Television and Oscilloscope Circuits
- Vibrator Buffer and Arc Elimination
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Write for illustrated literature featuring our complete line of Glassmike Capacitors.

***PLASTICONS: Plastic-Film Dielectric Capacitors**

Order from your jobber: If he cannot supply you, order direct

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for PRECISION TESTING

MODEL 1750
Load Range 200-2000 V.A.
Input Frequency Range 50-70 cycles
Input Voltage 95-125
Output Voltage 115-120 (Adjustable)
Response Time—6 cycles max.

Standardizing the "POP" in Toasters 24 Hours a Day *Without Burning a Slice...*

SORENSEN Regulators straighten out weaving input voltages. It's done the electronic way... without moving a muscle. No moving parts assure you of quick response, low maintenance and longer life.

Protecting costly laboratory apparatus from overvoltages, speeding up assembly line testing or applied to any of your regulation problems, the SORENSEN Regulator can be counted on to do the job with precision and accuracy.

Write for more information.
Arrange for a demonstration today.

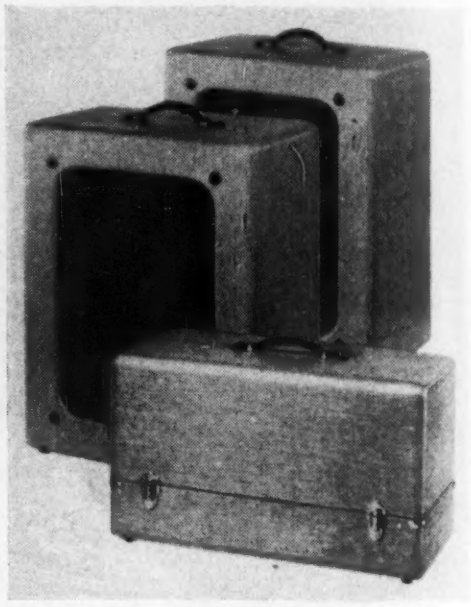
A LINE OF STANDARD REGULATORS FOR LOAD RANGES UP TO 5000 V.A.
SPECIAL UNITS DESIGNED TO FIT YOUR UNUSUAL APPLICATIONS.

SORENSEN & COMPANY
SORENSEN & COMPANY, INC.
STAMFORD, CONN.

modulation, sonic depth finders, geophysical exploration and loran equipments has recently been announced. Included is a 5-inch cathode-ray oscilloscope, trigger generator and adjustable time delay circuits. Sweep speeds up to 5 inches a microsecond are possible with the sweep triggered by either positive or negative pulses. Internal trigger outputs of 500, 1,000, 2,000 and 5,000 pulses per second are available.

Portable Sound System (30)

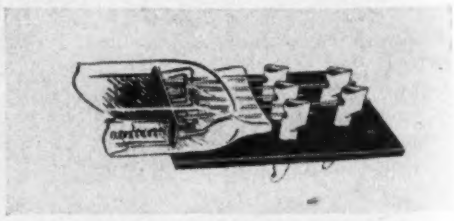
NEWCOMB AUDIO PRODUCTS Co., 2815 S. Hill St., Los Angeles 7, Calif. A new portable sound system contained in three carrying cases

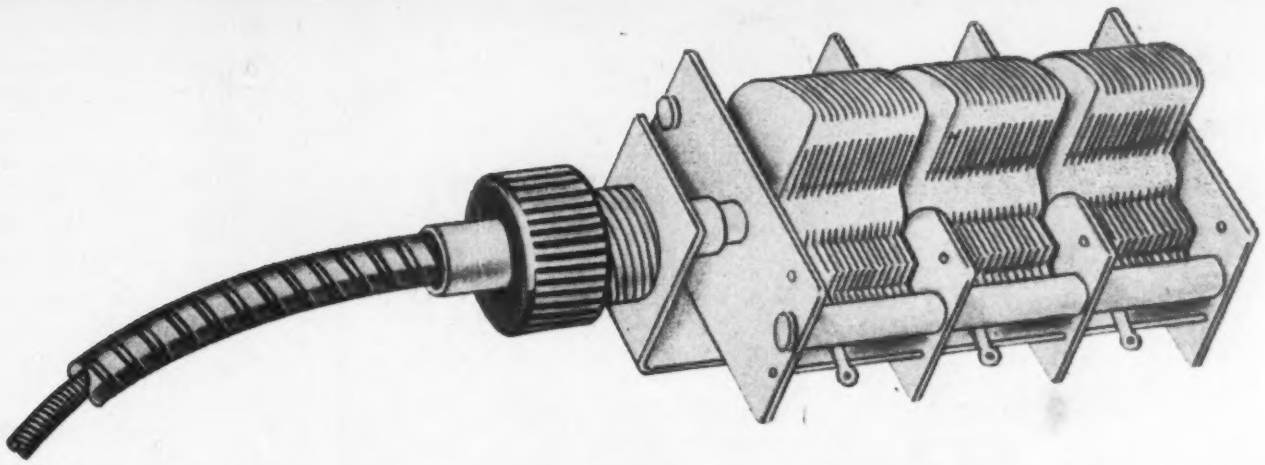


uses a 30-watt amplifier and two 12-inch speakers. Weight of the Model KX-30R12A equipment is 147 pounds.

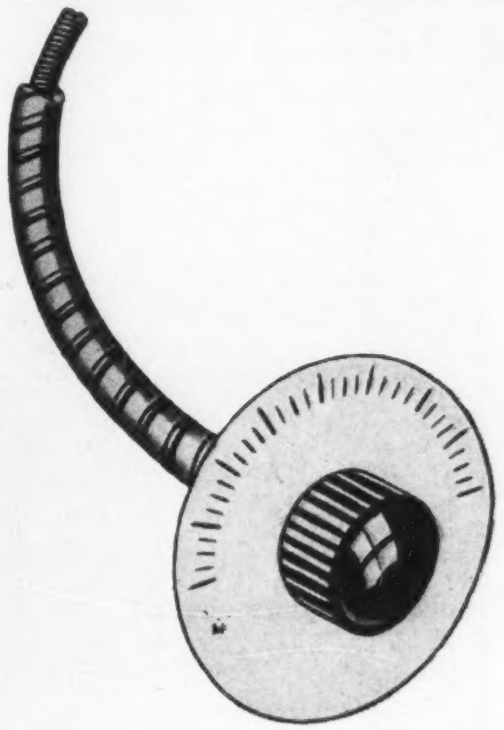
Subminiature Socket (31)

INSTRUMENT SPECIALTIES Co., Inc., Little Falls, N. J. A somewhat un-





Put FLEXIBILITY into ELECTRONIC DESIGN



When you make a circuit diagram, you put variable elements where you want them to simplify the design. You can gain the same "flexibility" when you design the actual equipment. Here's how—

DO IT WITH S.S.WHITE FLEXIBLE SHAFTS

When you couple variable elements to their controls with S.S.White Remote Control Flexible Shafts you have complete freedom in locating the elements where they best satisfy assembly, wiring and servicing requirements—and at the same time you have equal freedom in placing the control dials for convenient operation and harmonious appearance. For details—

WRITE FOR BULLETIN 4501

It gives essential facts and engineering data about flexible shafts and their application. Copy mailed on request.

S.S.WHITE INDUSTRIAL DIVISION

THE S. S. WHITE DENTAL MFG. CO.

DEPT. E, 10 EAST 40th ST., NEW YORK 16, N. Y.

FLEXIBLE SHAFTS • FLEXIBLE SHAFT TOOLS • AIRCRAFT ACCESSORIES
SMALL CUTTING AND GRINDING TOOLS • SPECIAL FORMULA RUBBERS
MOLDED RESISTORS • PLASTIC SPECIALTIES • CONTRACT PLASTICS MOLDING

One of America's AAAA Industrial Enterprises

high vacuum

RECORD AND CONTROL WITH

TELEVAC

TWO NEW VACUUM GAUGES ARE NOW AVAILABLE.

FOR COMPLETE SPECIFICATIONS, WRITE FOR BULLETIN **E-101**

- No Outgassing of Gauges
- Stable Calibration
- No Electrical Leakage
- Interchangeable Gauges
- Gauges Guaranteed 1000 Hours
- Can Not Burn Out Due to Accidents
- Dual Range: 0 to 500μ—0 to 0.4μ
- Adaptable to All High Vacuum Processes
- Extremely Simple to Operate
- Accurate, Continuous Record Tells the Whole Story—Permanently

MODEL S TELEVAC FOR ACCURATE RECORDS DOWN TO **.001 MICRON** (10^{-6} mm MERCURY)

MODEL MR TELEVAC FOR ACCURATE RECORDS DOWN TO **1 MICRON**

- Constant Calibration
- Interchangeable Gauges
- No Batteries—Uses 115V.A.C.
- Range: 0-500 Microns
- Adapatable to Automatic Exhaust Machines
- Can Operate Auxiliary Relays at Pre-determined Pressures

Manufacturers of Scientific Glassware and Precision Instruments for Over 10 Years

GEORGE E. FREDERICKS COMPANY

BETHAYRES PENNSYLVANIA

HIGH VACUUM TECHNICIANS • CONSULTING ENGINEERS

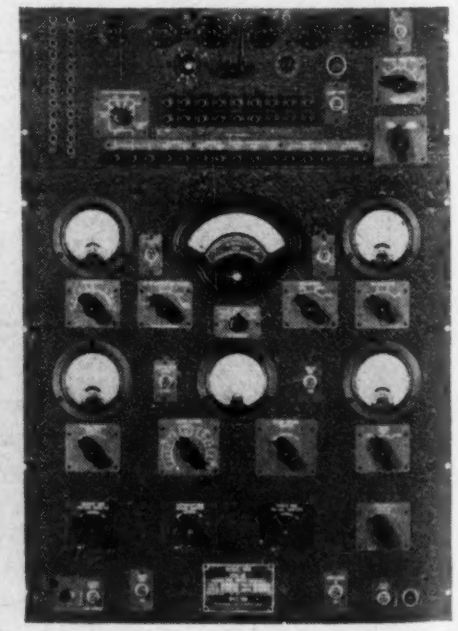
usual socket is now available for subminiature tubes having coplanar leads spaced 0.050 inch or more. The contacts, illustrated, are formed in an open U section then wedged into a square hole in a supporting insulating sheet. Tube wires or miniature prongs pass through a hole and are seized on the other side by the spring metal. Connecting wires are soldered to the projections on the other side of the supporting insulator.

Regulated D-C Power Supplies (32)

SORENSEN AND CO., Inc., 375 Fairfield Ave., Stamford, Conn. Regulated d-c power is available at either 6 or 12 volts in current ratings between 5 and 15 amperes. Operating from conventional a-c power lines, these regulators maintain their d-c output with an accuracy of plus or minus 0.5 percent.

Dynamic Tube Analyzer (33)

WESTON ELECTRICAL INSTRUMENT CORP., 617 Frelinghuysen Ave., Newark 5, N. J. The Model 686 vacuum tube analyzer tests tubes under dynamic operating conditions. A large meter indicates mutual conductance in ranges of 3,000, 6,000, and 15,000 micromhos. A socket panel provides access to



WILCO CONTACTS

They keep the power flowing!

Today WILCO CONTACTS keep the power flowing in vital industrial applications through their *built-in* capacity for precision performance and longer service life. WILCO CONTACTS function dependably in frequency operations of every range by bringing to each operation requisite ductility, hardness, density, freedom from sticking, low metal transfer, high conductivity and arc-resistance.

You likewise can depend on WILCO CONTACTS to keep the power flowing in your products, because exclusive patented WILCO processes assure unequalled qualities. WILCO engineers will gladly help you select from a great variety of available WILCO contact materials the particular contacts suited to your needs—or develop new alloys for special purposes.

WILCO PRODUCTS INCLUDE:

CONTACTS
Silver - Platinum - Tungsten - Alloys
Sintered Powder Metal

THERMOSTATIC BIMETAL
All temperature ranges, deflection rates and electrical resistivities.

SILVER CLAD STEEL JACKETED WIRE
Silver on Steel, Copper, Invar or other combinations requested.

ROLLED GOLD PLATE AND WIRE

SPECIAL ALLOYS

NI-SPAN C*
New Constant Modulus Alloy

* Reg. Trade Mark, The International Nickel Co., Inc.

THE H. A. WILSON COMPANY
105 Chestnut Street, Newark 5, N. J. • *Branch Offices:* Chicago, Detroit, Los Angeles, Providence

SPECIALISTS FOR 30 YEARS IN THE MANUFACTURE OF THERMOMETALS • ELECTRICAL CONTACTS • PRECIOUS METAL BIMETALLIC PRODUCTS

ELECTRONIC REGULATED POWER SUPPLIES

Precision *Accuracy* *Performance*

IMMEDIATE DELIVERY

Specifications:

Input: 115 V. 50-60 cycle.
Regulation: Less than 1/10 volt change in output voltage with change of from 85 to 145 V.A.C. input voltage and from NO LOAD to FULL LOAD (over very wide latitude at center of variable range.)
Ripple: Less than 5 millivolts at all loads and voltages.
Fits any standard 19" rack or cabinet.

TYPE A: Variable from 210 to 335 V.D.C. at 400 M.A.
TYPE B: Variable from 535 to 915 V.D.C. at 125 M.A.

Designed by one of the foremost electronic communication laboratories in the country; constructed by its equally noted associate company; and built for the U. S. Army as Power Supply RA-57-A to be used in conjunction with the microwave RADAR set SCR 547. Equipment was never used and was obtained in their original packing crates.

Adapted to civilian use by mounting on 12¼" x 19" panel, black crackle finish, and installing milliammeters, voltmeters, fuses, switches, pilot lights, terminals, power cords, and all other necessary auxiliary items.

Construction Features:

Weston Model 301 (or equal) Milliammeter and Voltmeter.
Separate switches, pilot lights, and fuses for FILAMENT AND PLATE VOLTS.
All tubes located on shockmount assemblies.
Fuses mounted on front panel and easily accessible.
Can vary voltage by turning small knob located on front of panel.
Can easily modify unit from positive to negative output voltage by changing two leads.
All individual components numbered to correspond with numbers on wiring diagram.
Rigid Construction: Individual components were designed to withstand the most severe military conditions—both physical and electrical—and were greatly under-rated.

Tube complement, Type A: 2-836; 6-6L6; 2-6SF5; 1-VR150; 1-VR105
Type B: 2-836; 2-6L6; 2-6SF5; 1-VR150; 1-VR105

Overall dimensions: 19" wide, 12¼" high, 11" deep.

Net weight: 80 pounds. Shipping weight: 95 pounds.

Some of the current users of these power supplies include nationally known electronic and communications measurement laboratories; aircraft, metallurgical and chemical research labs; technical schools; commercial radio, F.M. and television stations; amateurs; civilian RADAR installations; etc.

All units checked and inspected at 150% rated load before shipment.

NET PRICE: Type A: $175.00; Type B: $168.00 F.O.B. Baltimore

Prices subject to change without notice

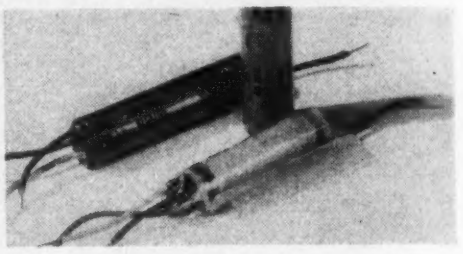
NATIONAL RADIO SERVICE CO.

Reisterstown Rd. & Cold Spring Lane **Baltimore 15, Md.**

each tube element and patch cords are used to set up circuits for the study of any tube. Plate, grid and other element potentials as well as signal voltages are provided in the analyzer.

Plastic Electrolytics (34)

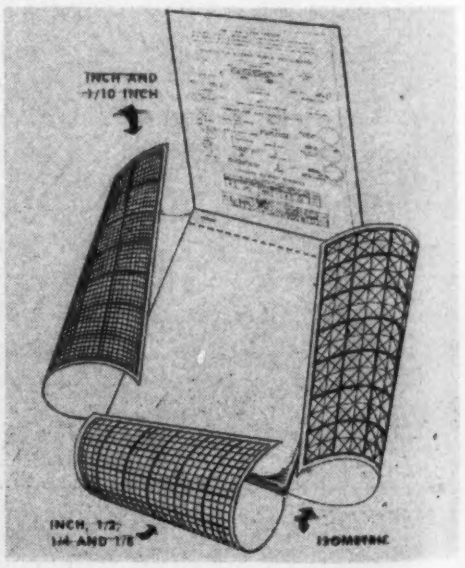
SOLAR MFG. CORP., 285 Madison Ave., New York 17, N. Y. Type DS, DT and DH dry electrolytic capacitors are now being wrapped in a



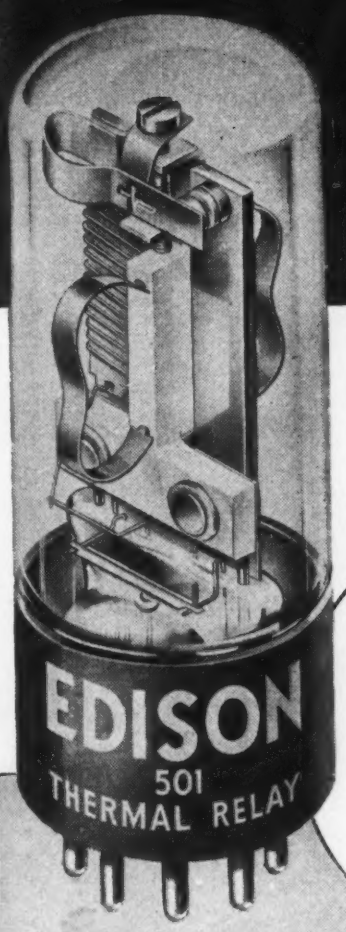
plastic film instead of Kraft paper liners before insertion in the cardboard housing. The film has been chosen to withstand the high potting temperatures and is said to increase the life of the capacitors materially.

Graphic Sketch Pad (35)

JIFFY SALES CO., 1879 East 37th St., Cleveland 14, Ohio. A pad of plain paper perforated for easy removal can be backed by one of three scales printed on cardboard flaps. Isometric, one-inch and tenths, or one-



What can this NEW Thermal Relay do for you?



Here are its characteristics. How can it fit your needs?

FEATURES:

Inexpensive, small, light...

Hermetic sealed, contacts totally enclosed and protected from dust, dirt and corrosion...

Long operating life...

Operates in any position, at any altitude...

AC/DC Operation, both heater and contacts operate interchangeably on AC or DC

OPERATING CHARACTERISTICS:

- **CONTACT RATING—6 amps. at 450 volts AC or DC (maximum).**
- **HEATER INPUT—5 watts nominal continuous excitation at up to 150 volts AC/DC.**
- **DELAY PERIOD—5 seconds to 8 minutes, preset at factory.**
- **CONTACTS—s.p.s.t.; normally open or normally closed.**
- **DIMENSIONS—1¼" dia. x 3¼" height (seated).**
- **AMBIENT RANGE—compensated for operation from —65°C to +100°C.**
- **WEIGHT—0.08 lb.**
- **MOUNTING—Standard octal or 4-pronged tube base.**

In a thermal relay, an electrical heater, rather than magnetic coil, is used to operate the contacts. This results in certain useful characteristics—inbuilt delay timing, insensitivity to transients, a non-inductive device that operates from AC or DC or interchangeably, and simple construction.

The design of the EDISON Model 501 Thermal Relay adds certain important features to these general advantages. Hermetic sealing in glass protects all parts, guarantees consistent long life, and makes operation independent of altitude. Contacts operate noiselessly in an arc-quenching atmosphere with consequent equal current ratings on AC or DC. A compensating bi-metal assures uniform response time at all ambient temperatures. The relay will operate in any position. A convenient tube-base mounting is available. Sound thermodynamic design assures consistent operation and permits a wide range of characteristics.

Delay or timing is only one of the many uses of this versatile new relay. Engineers are constantly finding new applications for a device with its unusual and useful characteristics—applications which simplify and improve control circuits of many types.

For instance, it protects vacuum tubes by delaying the application of plate current until cathodes are hot. It will indicate or control over and under-current, over and under-voltage. It carries heavy AC and DC loads and prevents chatter when actuated by delicate controls. It does dozens of other jobs better and more cheaply than any other type of relay.

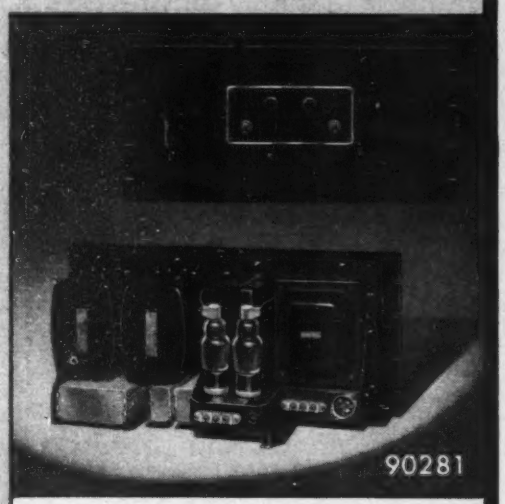
AN **EDISON** CONTROL

The services of Edison Engineers are available to assist you in working out any problem in connection with Edison instruments and controls. A letter giving as much data as possible on the proposed use will receive prompt attention. Instrument Division, Thomas A. Edison, Incorporated, 21 Lakeside Avenue, West Orange, N. J.

Designed for

M

Application



The No. 90281

High Voltage Power Supply

The No. 90281 h gh vo tage power supply has a d.c. output of 700 volts, with maximum current of 250 ma. In addition, AC filament power of 6.3 volts at 4 amperes is also available so that this power supply is an ideal unit for use with transmitters, such as the Millen No. 90800, as well as general laboratory purposes.

The power supply uses two No. 816 rectifiers and has a two section π filter with 10 henry General Electric chokes and a 2-2-10 mfd. bank of 1000 volt General Electric Pyranol capacitors. The panel is standard 8¾" x 19" rack mounting.

JAMES MILLEN MFG. CO., INC.

MAIN OFFICE AND FACTORY

MALDEN

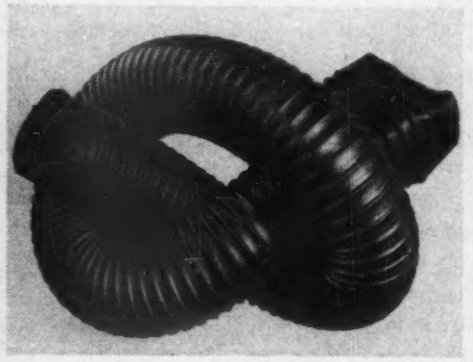
MASSACHUSETTS

M

inch, half, quarter and eighth-inch scales are available. Electronic, power and welding symbols are printed on the back of the cover. Price is $1.65 each, or less in lots.

Ventilating Hose (36)

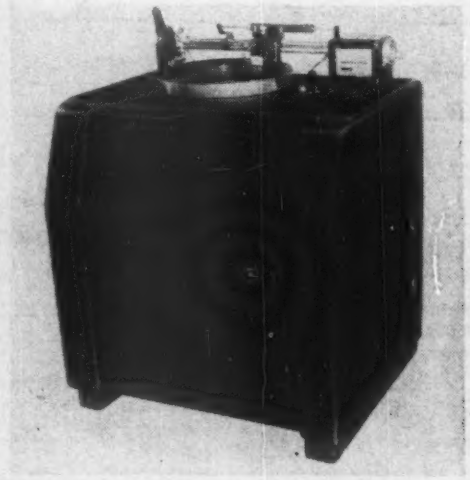
AMERICAN VENTILATING HOSE CO., 15 Park Row, New York 7, N. Y. A new neoprene-coated fabric hose



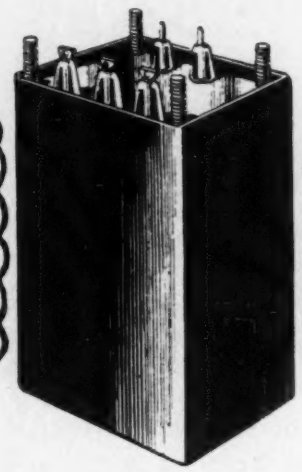
is available in diameters from 1 to 24 inches. Reinforced by a spiral wire, it can be used for a variety of cooling or ventilating purposes.

Studio Recorder (37)

FAIRCHILD CAMERA AND INSTRUMENT CORP., Jamaica, N. Y. The No. 523 studio recorder for instantaneous or wax recordings accommodates 18-inch masters. A positive drive at 33.3 rpm from a synchonous motor makes the a-c line the only standard of frequency necessary for dubbing in sound. Uniform



From out of the west... America's finest transformers



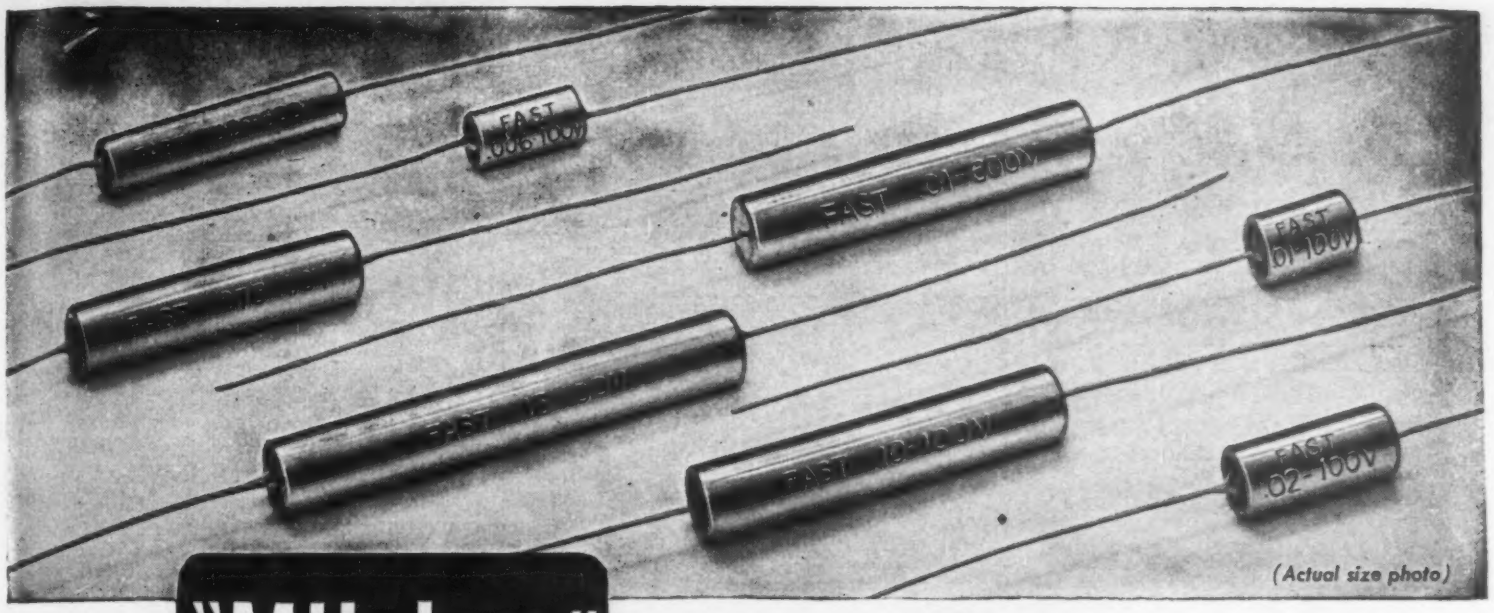
Thermador is a name remembered when the utmost in transformer quality is desired, and when exceptional engineering skill is required.

"Seven Leagues Ahead"

THERMADOR

THERMADOR ELECTRICAL MFG. CO.

5119 District Blvd., Los Angeles 22, California



(Actual size photo)

FAST "Mijakon" HERMETICALLY SEALED TUBULAR *Capacitors*

*H*ere is a line of **midget size** Capacitors that will fit into those many inaccessible places encountered in ELECTRONIC DEVICES, RADIOS AND TELEVISION SETS.

These are hermetically sealed *"Paper Dielectric"* units – impregnated and filled with oil* or wax – in tubular containers of brass with a heavy tin dip.

They are particularly suitable where a high quality capacitor is required to function under conditions of excess humidity; where stability and long life also are vital factors. They are fungus resistant – excellent units to use in radionic and electronic equipment for operation in tropical or similar areas. In certain regions servicing may be a problem, consequently continuous and reliable performance is essential.

This line includes the following ranges: In WAX – .002 to .1 MFD, 100 VDC; .002 to .075 MFD, 200 VDC; .002 to .05 MFD, 400 VDC; .001 to .03 MFD, 600 VDC. In OIL – .002 to .05 MFD, 100 and 200 VDC; .001 to .04 MFD, 400 VDC; .001 to .02 MFD, 600 VDC. Somewhat higher capacities can be supplied without increasing the size abnormally. Below is a Representative list of "MIJAKONS" showing detailed dimensions.

Please note these units are not carried in stock. Due to the difficulty in obtaining brass shells and tubing deliveries cannot be made until the end of the 1st quarter of 1947. Plan to use "MIJAKONS" in your 1947 models. Samples may be supplied in four to six weeks. WHEN MAKING INQUIRIES or REQUESTING samples PLEASE SPECIFY whether "Wax" or "Oil" are required.

Class 20—Both Terminals Insulated					Class 22—One Terminal Grounded				
Cap. Mfds.	Volts D.C.	Impregnant	Diameter (inches)	Length (inches)	Cap. Mfds.	Volts D.C.	Impregnant	Diameter (inches)	Length (inches)
.05	100	Oil	5/16	1–7/16	.008	100	Oil	9/32	9/16
.10	100	Wax	5/16	1–13/16	.075	100	Wax	19/64	1–3/8
.04	200	Oil	5/16	1–11/16	.004	200	Oil	1/4	3/4
.003	200	Wax	1/4	5/8	.002	200	Wax	1/4	1/2
.02	400	Oil	19/64	1–7/16	.001	400	Oil	1/4	5/8
.01	400	Wax	19/64	13/16	.05	400	Wax	5/16	1–3/4
.005	600	Oil	19/64	1	.01	600	Oil	19/64	1–3/8
.03	600	Wax	5/16	1–15/16	.02	600	Wax	5/16	1–3/8
.001	600	Oil	1/4	13/16	.005	600	Oil	19/64	15/16

WAX impregnated and filled units may be used for operation in temperatures up to 150°F (65°C) – the OIL Group up to 194°F (90°C).*

Standard Capacity Tolerance on "Mijakons" is ±20%. Closer tolerances may be obtained if required but at added cost.

*MINERAL OIL

Standard or Special Units to Meet Every Need

FAST can supply practically any Capacitor of the "Paper Dielectric" type in OIL or WAX — impregnated and filled — or POLYSTYRENE FILM. Containers may be cardboard or metal, rectangular or tubular, in sizes from the smallest to the largest. CHOKE COILS of heavy wire (No. 12 to No. 18), Air or Iron Core, can also be made to your specifications.

"When You Think of Capacitors . . . Think FAST"

JOHN E. FAST & CO.

Capacitor Specialists for Over a Quarter-Century

3101 N. Pulaski Road, Chicago 41

Canadian Representatives: Beaupre Engineering Works, Reg'd. 2101 Bennett Avenue, Montreal, for Power Factor Correction
J. R. Longstaffe, Ltd., 11 King Street, W., Toronto 1, for Special Applications

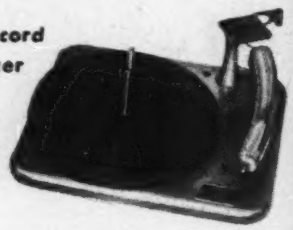
Harvey has record changers

Harvey is headquarters for sound equipment. In stock are record players, changers, amplifiers, speakers, mikes, complete p.a. and sound systems, etc. Take advantage of our fast efficient service...send or call in your orders!

RECORD CHANGERS

Utah Record Changer

$18.26



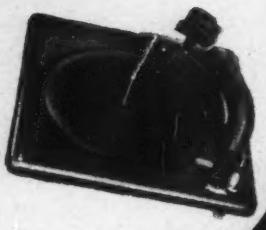
Utah Record Player—Same model, available in attractive pearl finish cabinet with amplifier, speaker, tone and volume controls. High quality phonograph reproduction in a neat small unit.....$44.15

WEBSTER Model 50-1

$21.60

WEBSTER Model 56-1

$27.20



Thordarson 8-Watt Amplifier, Model 30W08—Ideal for phono or p.a. work. Has separate mike and phono controls, tone control. Finished in grey wrinkle, panel trimmed in green. Uses two 6J7, one 6L6G, one 5Y3GT.

Net price, less tubes.....$25.98
Kit of tubes..... 3.26

Also in stock, a complete line of permanent magnet speakers of all sizes, unmounted or in cabinets and baffles for indoor or outdoor use.

Telephone: LOngacre 3-1800

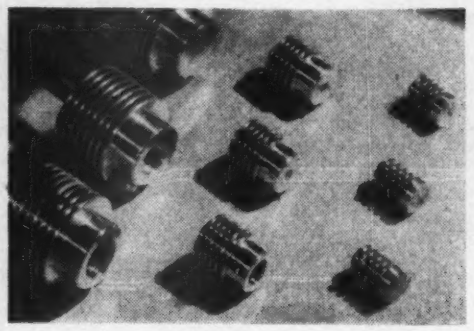
HRC HARVEY RADIO COMPANY INC.

103 West 43rd St., New York 18, N. Y.

cutting is assured with a screw mechanism adjustable at any pitch from 80 to 160 lines, starting either from center or edge.

Radiating Connectors (38)

EITEL-MCCULLOUGH, INC., San Bruno, Calif. Type HR heat dissipating connectors are used to make electrical connections to the plate and grid terminals of power tubes,



at the same time providing efficient heat transfer from the tube element and the glass seal to the air. The connectors are machined from solid dural rod and are supplied with necessary machine screws to insure a tight joint.

Multiwire Connectors (39)

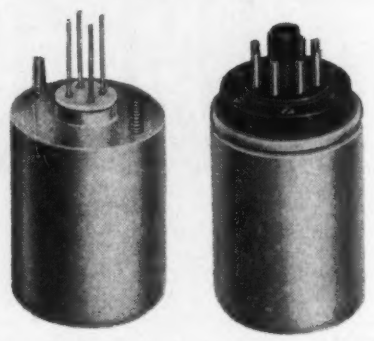
ALDEN PRODUCTS CO., 117 North Main St., Brockton 64, Mass. A new series of multiwire connectors features a knurled locking ring that engages slots in the chassis member. In the locked position a rubber gasket protects the junction from vibration and moisture. A means is provided for fastening cable shielding to obtain positive ground and prevent strain on the cable.

WHF Receiver (40)

RADIO RECEPTOR CO., INC., 251 West 19th St., New York 11, N. Y. The RV-1-B vhf crystal-controlled receiver is designed for fixed frequency service over the frequency

ADVANCE RELAYS

HERMETICALLY SEALED RELAYS



C-5 C-12

Advance hermetically sealed relays maintain their original efficiency under adverse conditions. Dust, moisture, oil or fungus cannot reach precisely adjusted parts. Approved for installation as non-sparking equipment where there is danger from inflammable vapors. Also eliminate failure due to arcing or condensation in low atmospheric pressures. Properly adjusted at the factory, they maintain adjustment in spite of temperature variation, and also are tamper proof.

Model C-5 relay can enclose Series 1500-1600 or Series 6000 (midget telephone type relay). Two mounting screws are provided. All connections solder to terminal wires projecting through the ceramic Steatite insulation disc. Available in models up to 4 pole double throw with either AC or DC coils. Overall size: 1⅝-in. diam. by 2¼-in. high.

The C-12 is an octal base, plug-in type relay of similar size to C-5 but installed like a radio vacuum tube. Insulation is Bakelite. Overall size 1⅝-in. diam. by 3½-in. high.

Any other Advance relays can be furnished on special order in hermetically sealed brass containers and with specified type of connections.

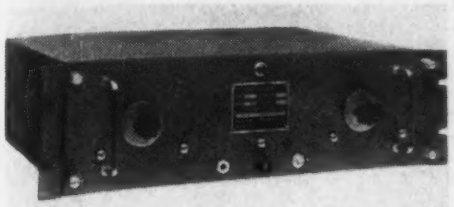
Our engineers are at your service. Let us work with you.

Advance Relays

ADVANCE ELECTRIC & RELAY CO.

1260 W. 2nd St., Los Angeles 26, Calif., U.S.A.

range 100 to 162 megacycles. The unit is rack-mounted for airline or other fixed station use but can be



slid out of its dust cover and inverted while in operation. Further details are given in Bulletin 5007A.

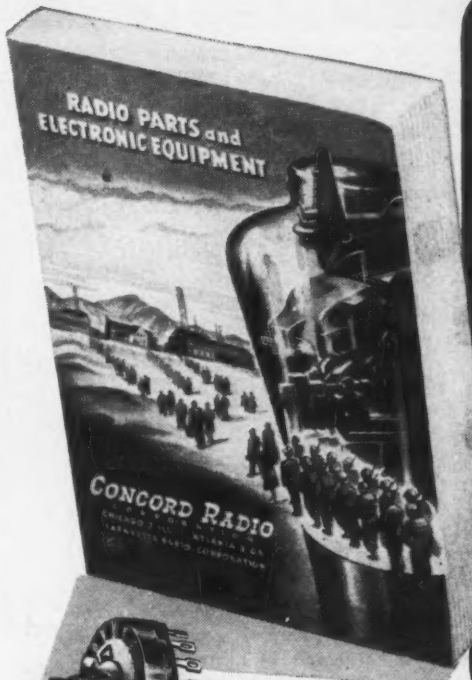
Resonant Relays (41)

STEVENS-ARNOLD Co., 22 Elkins St., South Boston 27, Mass. The type 172 resonant relay uses a vibrating

reed mechanism adjusted to respond to a narrow band of frequencies. The units are totally enclosed and based with octal-tube type connections. The ON time of the contacts is 5 percent for all frequencies from 153 to 442 cps. An auxiliary relay or vacuum tube is used to control large currents that can not be handled by the vibrating contacts. The standard coil has an impedance of 500 ohms. Further details are given in Catalog 116.

Level Recorder (42)

SOUND APPARATUS Co., 233 Broadway, New York 7, N. Y. The type PS portable graphic recorder measures only 8 x 10 x 12 inches and



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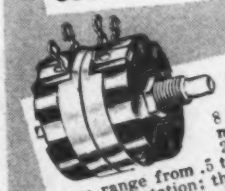
C3153 ..... 60¢



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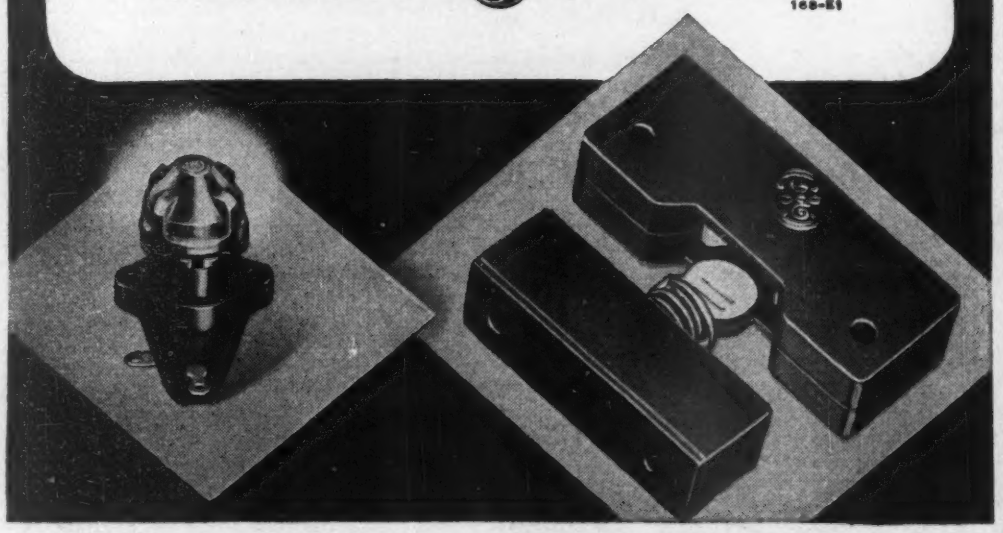

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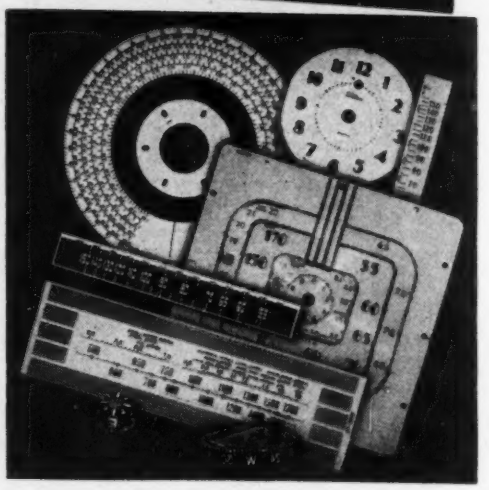

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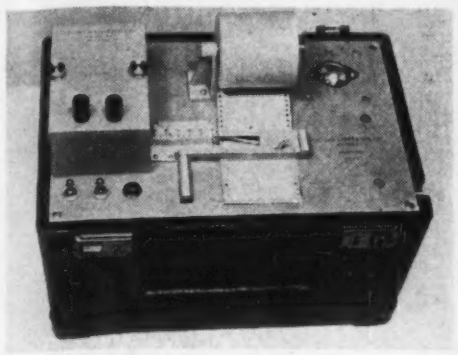
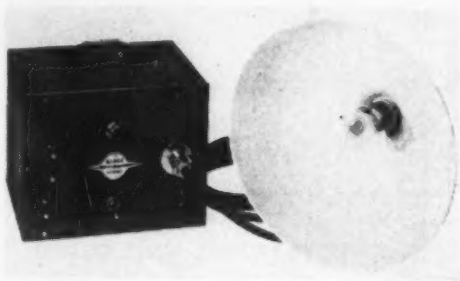


has a sensitivity of 10 millivolts for 0 db. Normal paper speed is 6 inches a minute. Recording speed is full scale in 0.6 second.

Stroboscopic Light (43)

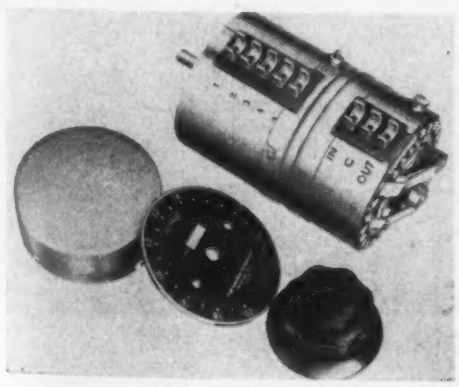
KLUGE ELECTRONICS CO., 1031 North Alvarado St., Los Angeles 26, Calif. A new portable strobo-



scopic lamp with a bulb giving sunlight values for color work operates from any a-c outlet and retails for $79.50 without tax.

Compensating Attenuator (44)

DAVEN CO., 191 CENTRAL AVE., Newark, N. J. The type LAC-720



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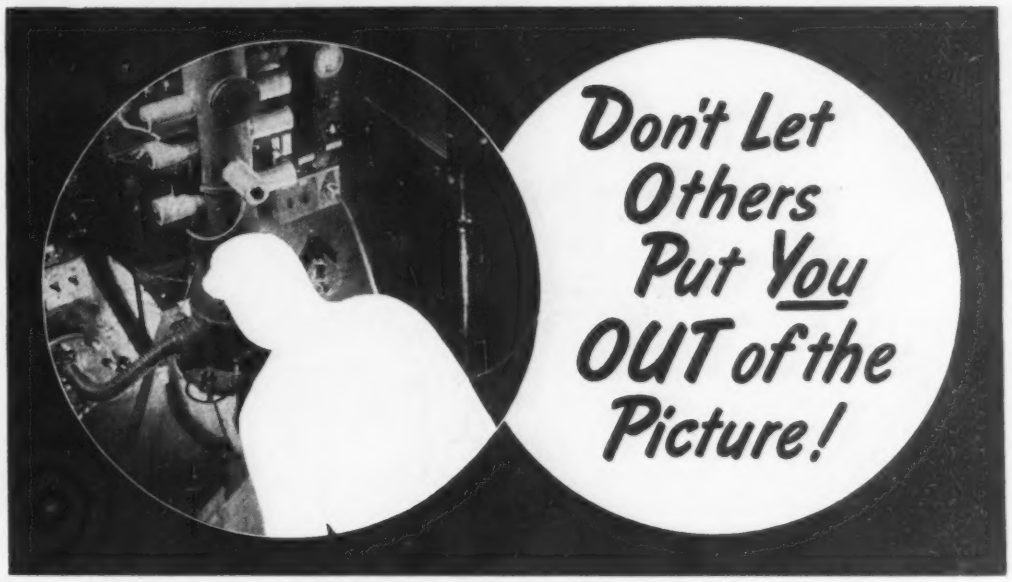

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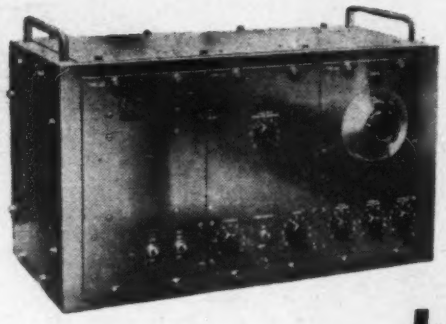

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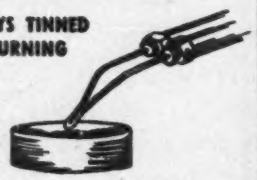

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The loop type tip gives you other advantages that are important in soldering. Good balance with weight close to your hand makes it easier to use. The narrow tip gets in between a lot of wiring with ease. Connections can be made without burning insulation. The tip can be formed readily to work in tight places.

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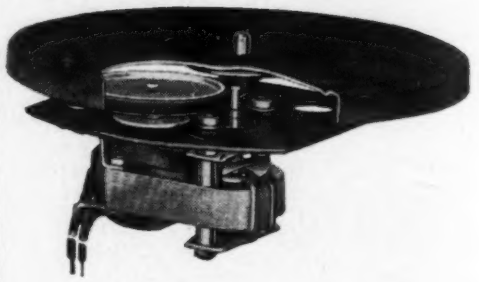

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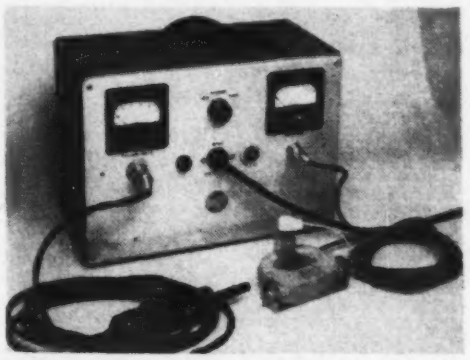
Timing Motor (45)

A. W. HAYDON ENGINEERING CO., Waterbury, Conn. The Circle B timing motor can be supplied in 1 and 5 rpm speeds, operating from 110, 220, and 24 volts, 60 cycles. It will fit in a 2-inch circle, has through holes for mounting, solder terminals, and no projecting ears or leads.

Vacuum Gage (46)

RADIO CORP. OF AMERICA, Camden, N. J. The type EMG vacuum gage used in the electron microscope is now available as a separate assembly consisting of thermocouple, ionization tube and control unit. Rough pumping pressures are



indicated by the thermocouple, whereas the tube is connected after the diffusion pump has been started. A feature of this tube is its cold cathode. There is no filament to burn out with accidental increase of air pressure. The tube is also enclosed in an oval metal shell surrounded by a strong magnetic field. The anode consists of a rectangular loop of wire embracing the maximum position of the

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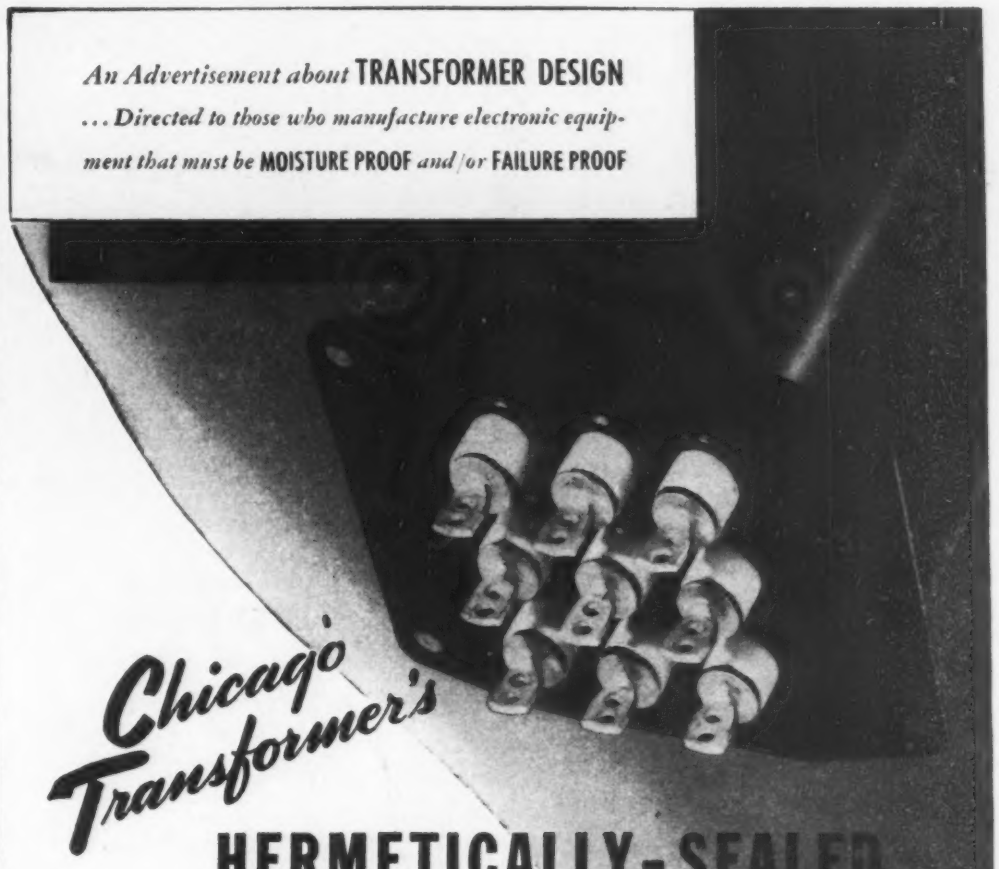

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DC SILICONES

DC 702 and DC 703
Silicone Diffusion Pump Fluids

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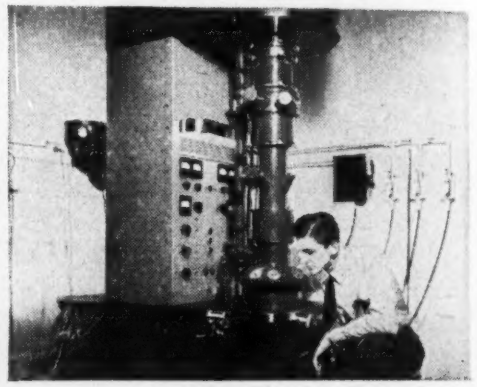

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- In metal evaporator systems
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DC 702 has a lower boiling point, operates against a higher forepressure and produces vacua in the range of organic diffusion pump oils.

Additional information about DC 702 and DC 703 is contained in pamphlet No. N 9-1.

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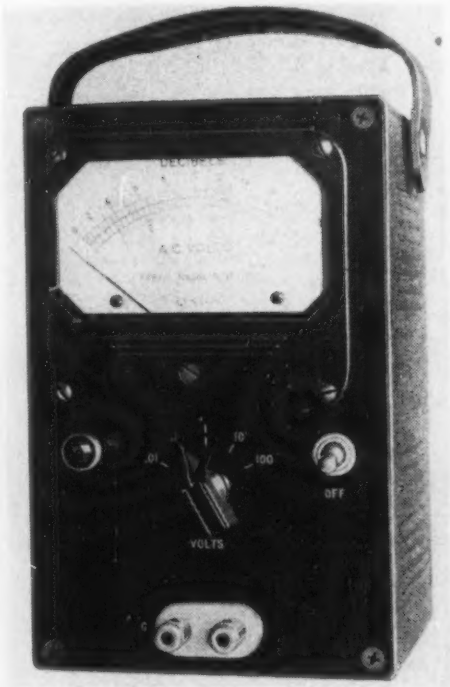
magnetic field. The gage units are provided with standard threaded fittings, and leads with plugs to attach to the appropriate jacks in the control unit. Pressures as low as 0.1 micron can be accurately measured.

V-T Voltmeter (47)

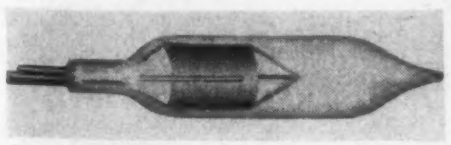
FREED TRANSFORMER CO., INC., 72 Spring St., New York, N. Y. The



No. 1040 vacuum-tube voltmeter has a range from 0.001 to 100 volts with an accuracy of 2 percent for sinusoidal voltages. Frequency range is 10 to 200,000 cycles with 0.1 db variation. The power supply is contained in the metal cabinet.

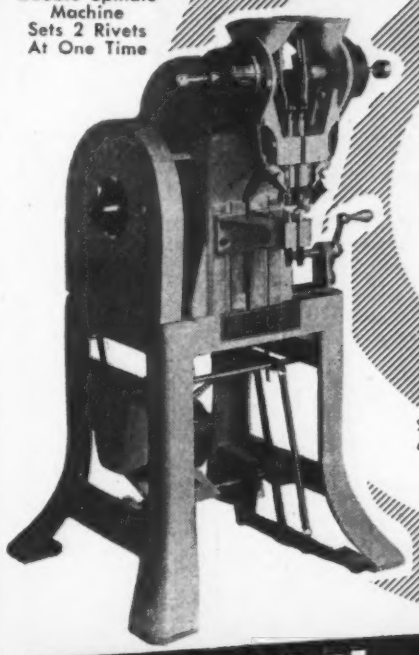
Miniature Phototubes (48)

CONTINENTAL ELECTRIC CO., Geneva, Ill. Cetron tubes CE-58 and CE-60 measure 1⅝ inches in length and have a diameter of 25/64 inch. The former tube is gas filled, has a red-sensitive surface and is available in two sensitivities, 80 or 150



Question for DESIGN and PRODUCTION ENGINEERS

MILFORD Double Spindle Machine Sets 2 Rivets At One Time



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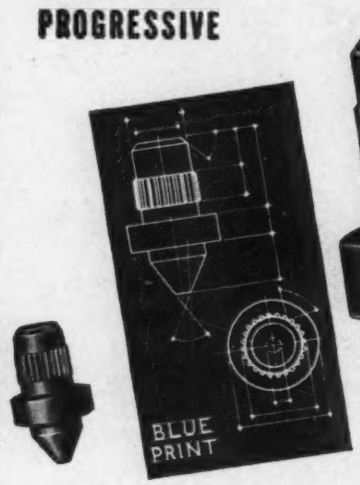

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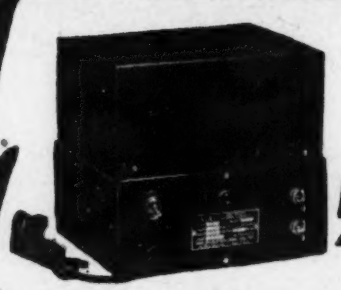

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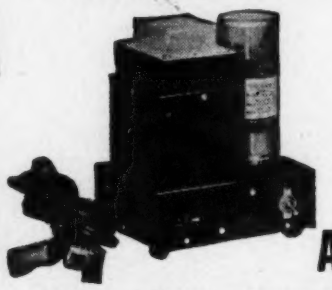

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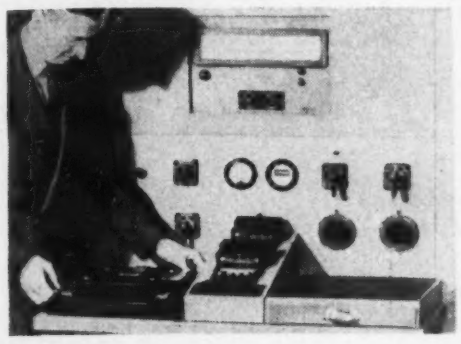
microamperes per lumen. The CE-60 is blue-sensitive with either standard commercial sensitivity of 14 microamperes per lumen, or 25 for experimental use. Detailed specifications are available.

Core-Loss Tester (49)

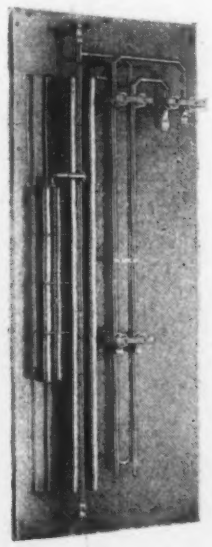
GENERAL ELECTRIC CO., SCHENECTADY, N. Y. A new instrument to measure a-c permeability and core loss in steel samples is a self-con-



tained, desk-type unit. The apparatus meets ASTM specifications for measurements at commercial power frequencies and inductions up to 18 kilogausses.

F-M Antenna Coupler (50)

E. F. JOHNSON CO., Waseca, Minn. Broadcasters desirous of using existing a-m transmitting towers for



initial f-m antenna installations are often faced with the problem of feeding the new antenna without short-circuiting the a-m radiator or

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Rotobridge indicates defective circuits by number, enabling a service man to examine the numbered inspection tag, and find the defect without the use of conventional measuring equipment.

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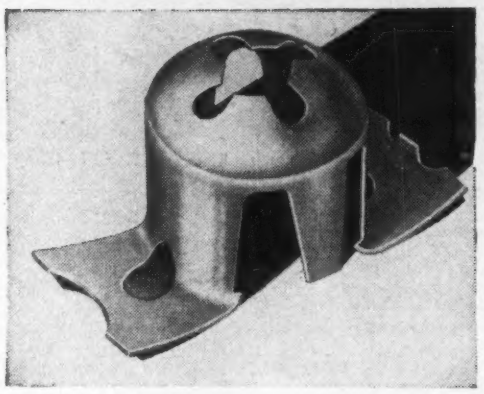

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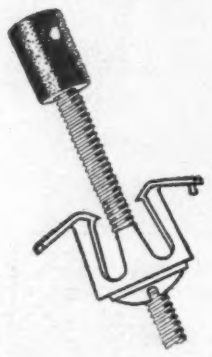

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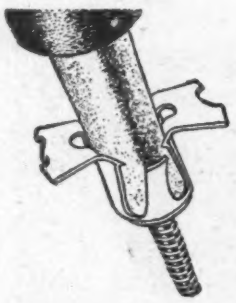

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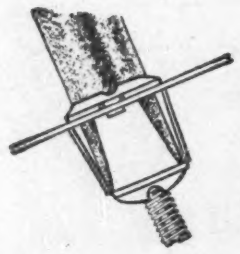

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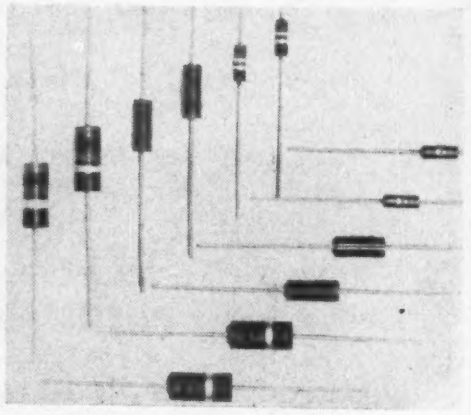
introducing crosstalk on the f-m frequency. The iso-coupler allows operation of 10-kilowatt f-m transmitters on 50-kilowatt a-m towers, matching 50-ohm lines from the f-m transmitter. The unit is furnished in a 94 x 37 x 24 inch outdoor cabinet.

Composition Resistors (51)

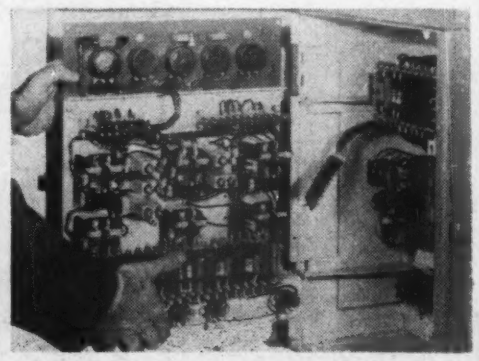
GENERAL ELECTRIC Co., Wolf St. Plant, Syracuse, N. Y. Composition resistors in standard RMA values capable of operation at full rating



up to 168 F have been announced. They are humidity-resistant and have strong pigtail leads that are heavily tinned. Up to 350 volts rms can be continuously applied across the half-watt unit and 1,000 volts across the two-watt resistor.

Welding Sequence Timer (52)

GENERAL ELECTRIC CO., SCHENECTADY, N. Y. A new line of sequence timers using electronic timing circuits has been developed. Quick change of welding sequence, easy



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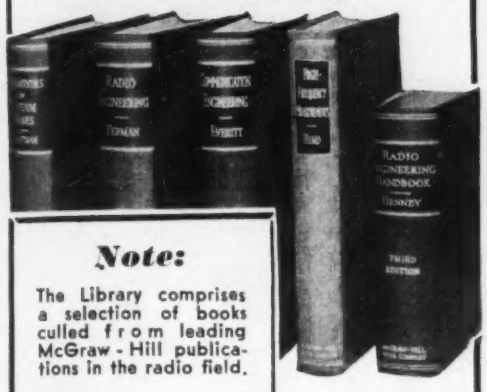

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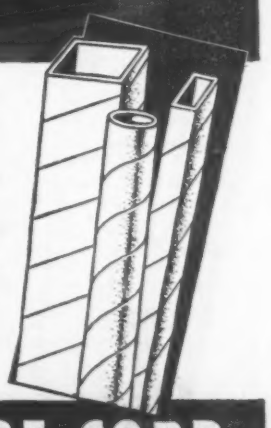

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plug connections for quick replacement. Bulletin GEA-3318B describes the equipment in detail.

Rotary Stylus Record (53)

CONNECTICUT TELEPHONE AND ELECTRIC DIVISION, Meriden, Conn. A new inkless recorder has been designed particularly for plotting 48 complete stress-strain diagrams at one time. The size of each diagram is 5 x 2½ inches. The number of scanning cycles for 48 gages is 8 per minute with a maximum sensitivity for full diagram height of 1,000 microinches per inch.

Literature

(54)

Receiver Information. Howard W. Sams & Co., 2924 East Washington St., Indianapolis, Ind. Photo Fact Folder Set No. 3 has recently been received by subscribers to the service. Each 4-page leaflet contains complete servicing information, photographs and a wiring diagram of a single broadcast receiver. When bound together, the leaflets form a complete service encyclopedia.

(55)

Fidelity Recorder. Electronic Chemical Engineering Co., 443 So. La Cienega, Los Angeles 36, Calif. The Electrone-Tone uses motion picture film for recording up to five tracks on a 16-mm strip. Other widths give a corresponding increase or decrease in the number of tracks. Film is developed in the conventional manner. A four-page booklet illustrates the equipment that is said to record up to 10,000 cycles.

(56)

Colloidal Graphite. Acheson Colloids Corp., Port Huron, Mich. Electronic applications of colloidal graphite for shielding, cathode-ray tube anode manufacture and building resistance layers

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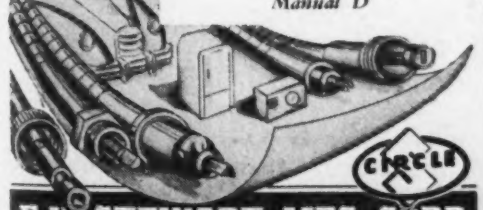

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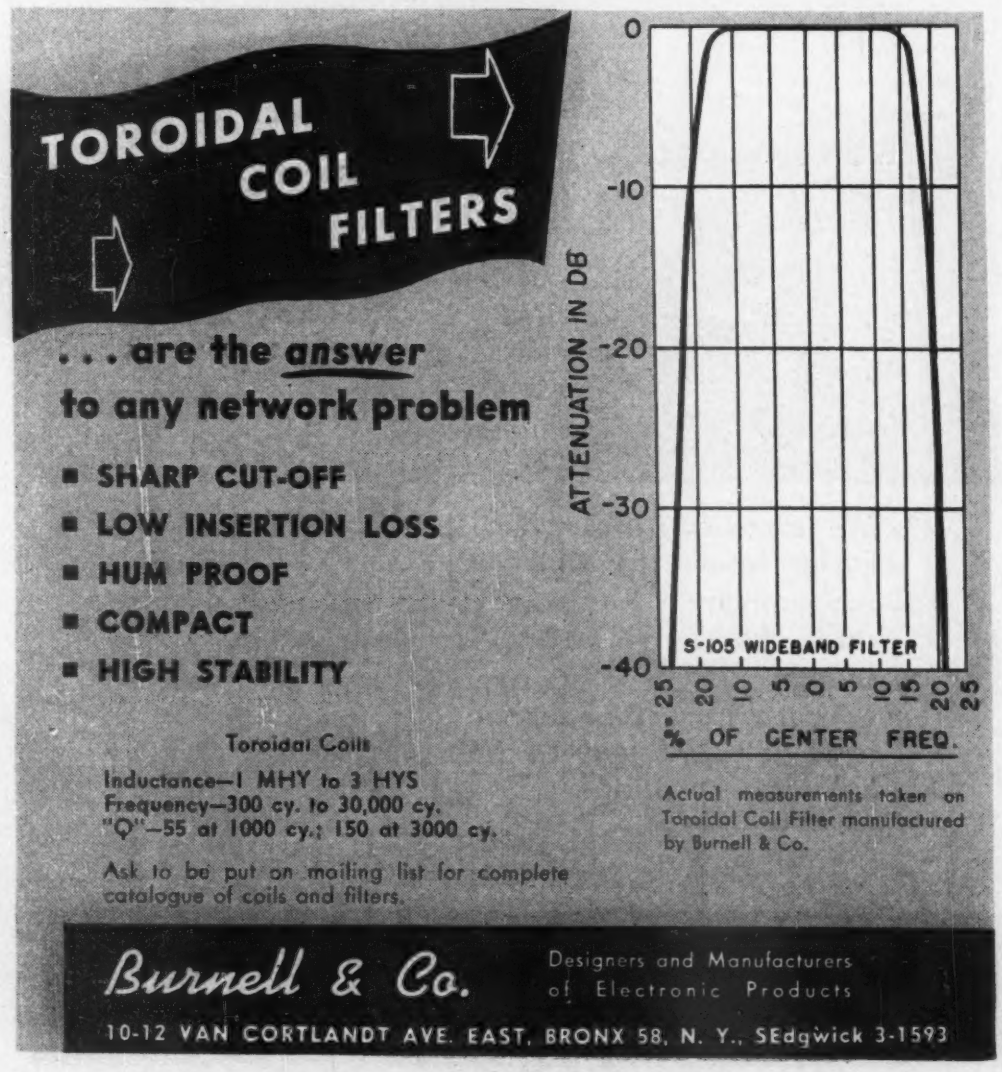
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are well known. A new technical bulletin presents the uses and characteristics of "dag" solutions.

(57)

Technical Publication Resumed. Collins Radio Co., Cedar Rapids, Iowa. "The Collins Signal" will shortly resume publication after a lapse of several years. Engineers desiring the free publication should write the editor.

(58)

Diffusion Pump Fluids. Dow Corning Corp., Midland, Mich. A pamphlet describes a method of obtaining high vacuums up to 5×10^{-9} by use of silicone fluids DC702 and DC703 to eliminate breakdown of pumps formerly using low-vapor-pressure fluids.

(59)

Fiber Insulation. Continental-Diamond Fibre Co., Newark, Delaware. Bulletin GF16 describes a half dozen types of insulating materials, their electrical and mechanical properties and possible uses in a 14-page booklet.

(60)

Rectifier Ratings. General Electric Co., Schenectady, N. Y. The industrial phanotron FG-32 is a low-frequency, low-voltage, high-current rectifier tube. Increased temperature ratings have just been announced and are listed in a publication of the Tube Division.

(61)

Rectifiers. W. Green Electric Co., Inc., 130 Cedar St., New York 16, N. Y. Three new rectifier publications and a file folder summarize the company's bench and telegraph type products.

(62)

Ship-to-Shore Radiophone. Radiomarine Corp. of America, 75 Varick St., New York 13, N. Y. Model ET-8027 radiotelephone equipment has six crystal-controlled channels and a power output of 25 watts. It operates in the frequency range

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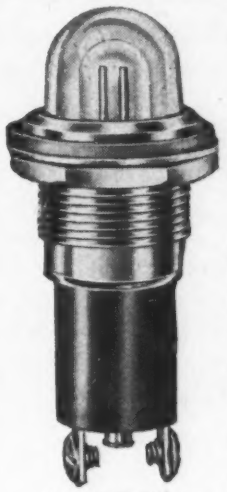

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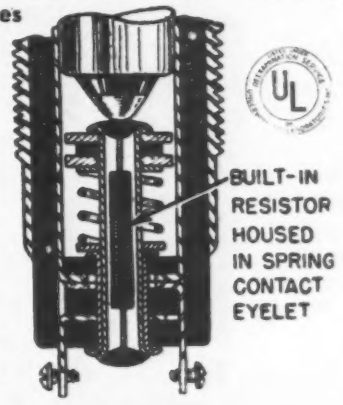

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Laboratory Standards

PULSE GENERATOR

MODEL 79-B

SPECIFICATIONS:

FREQUENCY: continuously variable 60 to 100,000 cycles.
PULSE WIDTH: continuously variable 0.5 to 40 microseconds.
OUTPUT VOLTAGE: Approximately 150 volts positive.
OUTPUT IMPEDANCE: 6Y6G cathode follower with 1000 ohm load.
R. F. MODULATOR: Built-in carrier modulator applies pulse modulation to any r.f. carrier below 100 mc.
MISCELLANEOUS: Displaced sync output, individually calibrated frequency and pulse width dials, 117 volt, 40-60 cycles operation, size 14"x10"x10", wt. 31 lbs.

Immediate Delivery

MEASUREMENTS CORPORATION

BOONTON • NEW JERSEY

2,000 to 3,500 kilocycles and is fully described in a 4-page bulletin PC101.

(63)

Thermal Relay. Thomas A. Edison, Inc., West Orange, N. J. The model 501 thermal relay is in effect a thermal time-delay device, preset and sealed. Publication No. 3007X tells all about it.

(64)

Contract Manufacturer. Lewyt Corp., 60 Broadway, Brooklyn 11, N. Y. Some of the manufacturing facilities and contracting arrangements of the company are described in newspaper clipping pasteup form bound into a 16-page brochure.

(65)

Connectors. Cannon Electric Development Co., 3209 Humboldt St., Los Angeles 31, Calif. Descriptive of applications is a 78-page looseleaf book picturing Cannon plugs. There is no specific engineering or ordering information in this interesting publication.

TELEVISION OVER BIKINI

Practicing for the atom bomb tests at Bikini, Captains Davis and Seldomridge direct the takeoff of a pilotless B-17. The television receiver in the foreground shows the instrument panel of the bomber while the small control box is used to direct the takeoff and landing. The mother plane controls the B-17 in the air

Better ATLAS SOUND Equipment Ready for YOU

DOUBLE REENTRANT PROJECTOR

Many sizes. From 15 in. air column to 6 foot air column.

360 RADIAL, CHANDELIER PROJECTORS

Double Reentrant. For driver units. 3 and 4 foot air column lengths.

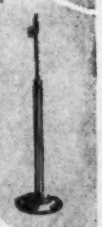
DRIVER UNITS
Various Power Handling Capacities. Newest types of Indestructible Phenolic Diaphragms.

MINIATURE TYPE REENTRANT PROJECTORS— BOOSTER SPEAKERS.

High-efficiency, Weather-proof. Complete with Driver Unit and Universal Bracket.

CONE TYPE PARABOLICS and CHANDELIER RAFFLES

for all size cone speakers. Wooden and Metal Cone Speaker Enclosures, Baffles, Carrying Cases, Loud Speaker Support Stands and Brackets.



MICROPHONE SUPPORT STANDS

20 types and sizes. All Fittings, Adaptors and Accessories. Floor Stands, Desk Stands, Banquet Stands, Room Stands.

Write for New Illustrated Catalog Sheets

ATLAS SOUND CORPORATION
1449 39th St., Brooklyn 18, N. Y.

DIALS
PLATES
PANELS

For thirty-five years we have been leaders, specializing in the creation and production of distinctive etched and lithographed products.
We serve the leaders of many industries, meeting their high standards of quality and precision workmanship.

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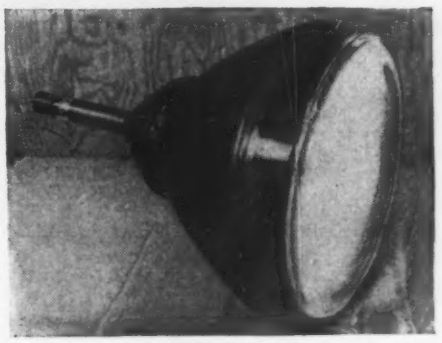
Premier
METAL ETCHING COMPANY
21-03 FORTY FOURTH AVENUE
LONG ISLAND CITY NEW YORK



NEW 15" TUBE *for Television*

High Vacuum, High Brilliance, Magnetic Focus & Deflection, Black & White Screen. Length 20¼". Face Plate approximately Flat. Operates anywhere from 8,000-15,000 Volts, best at 12,500 Volts. Write for full data. Also in production 12-inch magnetic tubes.

NO ION SPOTS — NO ION TRAP

ZETKA LABORATORIES, INC.
131 GETTY AVE., CLIFTON, NEW JERSEY

Affiliated with

UNITED STATES TELEVISION MFG. CORP.

ARGON HELIUM KRYPTON
NEON XENON MIXTURES

Linde

RARE GASES
AND MIXTURES

. . . Spectroscopically Pure

. . . Easily removed from bulb without contamination

Scientific uses for LINDE rare gases include—

1. The study of electrical discharges.
2. Work with rectifying and stroboscopic devices.
3. Metallurgical research.
4. Work with inert atmospheres, where heat conduction must be increased or decreased.

Many standard mixtures are available. Special mixtures for experimental purposes can be supplied upon request.

The word "Linde" is a trade-mark of

THE LINDE AIR PRODUCTS COMPANY
Unit of Union Carbide and Carbon Corporation
30 E. 42nd St., New York 17, N. Y. Two Offices in Principal Cities

The STOUT HEART of
World Famous
Hathaway **OSCILLOGRAPHS**
is the Type OA-2 Galvanometer

Bifilar moving element, low mass, ultra-simple, takes less driving energy.
Complete in one unit, with magnet and universal mounting.
Natural frequency, 10,000 cycles per sec.
Sensitivity to 50 millimeters per milliamperes at one meter.

There's a HATHAWAY Oscillograph to meet every requirement — Hathaway specialized service to help apply it to your problems. Write for information on Hathaway Oscillographs and Oscillograph Galvanometers. Hathaway Instrument Company, 1315 S. Clarkson St., Denver 10, Colorado.

Hathaway INSTRUMENTS

NEWS OF THE INDUSTRY

Edited by JOHN MARKUS

Rochester Fall Meeting announcement; radio production for August; color television demonstration; meetings to come

New RMA Tube Designations and Wiring Standards

TWO NEW RMA standards, a chassis wiring color code and a new type designation system for tubes other than receiving and cathode-ray types, have been approved by the Engineering Department of Radio Manufacturers Association and are now in effect among its members.

Where color coding is used, it shall be standard to employ the following schedule of solid colors for chassis hookup and component-lead wire insulation:

Black—Grounds, grounded elements, & returns
Brown—Heaters or filaments, off ground
Red—Power supply B plus
Orange—Screen grids
Yellow—Cathodes
Green—Control grids
Blue—Plates
Violet—Not used
Gray—A-C power lines
White—Above or below ground returns, avc, etc

For tubes and devices exclusive of receiving and cathode-ray tubes, the type designation shall consist of a pure numeric starting with 5500 and shall be assigned consecutively and chronologically in the order of type number request. A new type designation shall be assigned to a new version of a prototype whenever the new version is not completely interchangeable with the prototype. Whenever a new designation is assigned to a type which is unilaterally interchangeable with a former type, such interchangeability may be indicated by marking the new type with its assigned designation followed, at the option of the manufacturer, by the designation of the former type. The new system is not retroactive. Typical type designations are 5501, 5712, 5923, 6234, and 6545, as contrasted to designations like 1C23, 1N35, and 6D25 under the system previously in effect.

Moscow Radio Meeting

A FOURTEEN-MAN delegation from various government agencies represented the United States at a five-power preliminary telecommunications meeting held in Moscow recently for informal preliminary discussions aimed at convening of a world telecommunications conference sometime in 1947. This conference would revise the Madrid telecommunication convention of 1932, now in effect.

Navy Expands Training of Electronic Technicians

THE BASIC COURSE for electronic technician's mates in the Navy has been broadened from 20 weeks to 42 weeks, with classroom and

---

" . . . . PRODUCED MORE THAN FIFTY PERCENT OF ALL RADAR . . . . "

Clarence G. Stoll, president of Western Electric Co., receives the Medal for Merit, nation's highest civilian award, from Major General Harry C. Ingles, Chief Signal Officer. The accompanying citation reads in part, "Under his direction and outstanding leadership his Company produced more than 30 percent of all electronic and communications equipment and more than 50 percent of all radar manufactured in this country during the war."

Oliver E. Buckley, president of Bell Telephone Laboratories, also received from General Ingles on September 26, 1946 the Medal for Merit. The citation, signed by President Truman, reads in part, "He displayed great foresight by expediting development . . . even before its military value had become apparent, and his leadership was reflected in the highly effective collaboration of scientists and technicians. . . ."

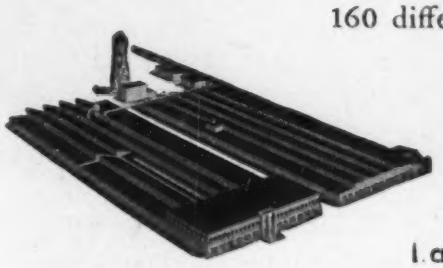
Almost every radio set made in recent years has a Magnavox speaker or other Magnavox components.

MAGNAVOX . . . first and foremost in the production of quality speakers

FOR 35 years Magnavox has specialized in speakers and speaker satisfaction. The oldest and largest manufacturer of loud speakers, Magnavox is established as *the standard of quality*.

Magnavox designers and engineers have achieved a breadth of experience and knowledge that enables them to meet your specifications exactly. Over 160 different speakers are produced expressly for the manufacturing trade.

Hard-to-satisfy research engineers constantly seek better speaker designs and production methods. They stand ready to apply their developments to your speaker problems. When you need speakers, specify Magnavox. There is no substitute for experience. The Magnavox Company, Components Division, Fort Wayne 4, Indiana.



Magnavox

has served the radio industry for over 30 years

SPEAKERS • CAPACITORS • ELECTRONIC EQUIPMENT

Electricity

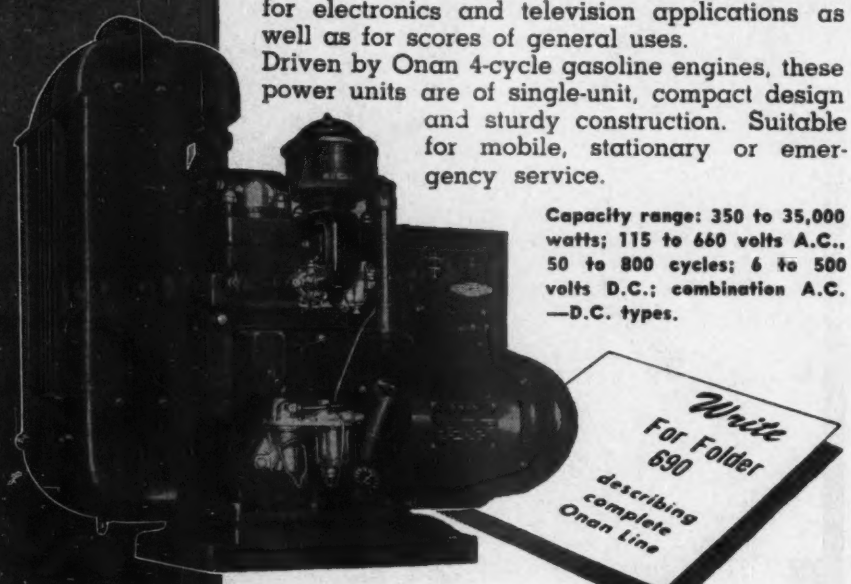
FOR RADIO AND ELECTRONIC APPLICATIONS

Onan ELECTRIC PLANTS

ONAN ELECTRIC GENERATING PLANTS supply reliable, economical electrical service for electronics and television applications as well as for scores of general uses.

Driven by Onan 4-cycle gasoline engines, these power units are of single-unit, compact design and sturdy construction. Suitable for mobile, stationary or emergency service.

Capacity range: 350 to 35,000 watts; 115 to 660 volts A.C., 50 to 800 cycles; 6 to 500 volts D.C.; combination A.C. —D.C. types.



Write For Folder 690 describing complete Onan Line

Model shown is from W2C series; 2000 to 3500 watts; powered by Onan two-cylinder, water-cooled engine

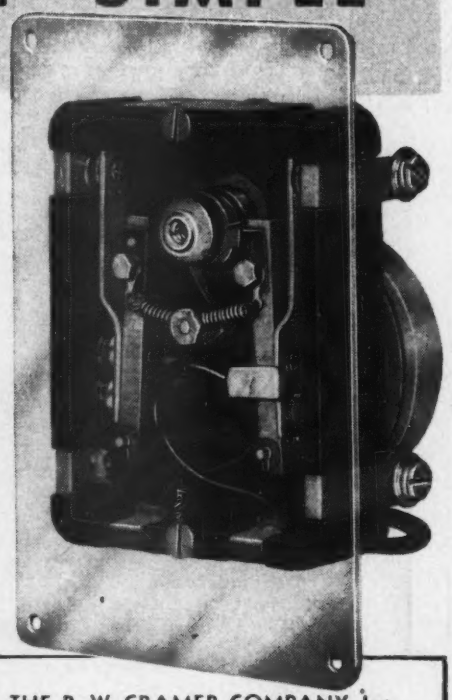
D. W. ONAN & SONS
3557 Royalston Ave. Minneapolis 5, Minn.

SAFE • SURE • SIMPLE

• • PROTECTION FOR COSTLY TUBES

Cramer PRECISION MODEL C TIME DELAY RELAY

Here is a simple, dependably accurate and rugged control which has been specified by many radio engineers because it has been especially designed for tube protection. Providing a fixed time delay (with adjustable feature), its flexibility of design permits special combinations and circuit arrangements which our Engineering Department can adapt to your requirements. Get the long run economy of accurate, highly dependable and ruggedly designed Cramer Time Controls at comparable initial cost. Write us today for engineering bulletins.



THE R. W. CRAMER COMPANY, Inc.
Box No. 3 Centerbrook, Conn.

Cramer

SPECIALISTS IN TIME AS A FACTOR OF CONTROL

INTERVAL • DELAY • CYCLE • IMPULSE • PERCENTAGE

laboratory instruction increased from 800 hours to 1,680 hours. Upon completion, the students receive practical experience at sea or shore stations before becoming eligible for the 28-week advanced course. These two courses cover radio, radar, sonar, loran, and other recently developed applications of a secret or confidential nature. In addition, advanced and specialized courses in specific equipments such as blind-landing and television are given.

Revisions in Program of Rochester Fall Meeting

THE TECHNICAL program of the Rochester Fall Meeting, scheduled for Nov. 11, 12, 13 at the Sheraton Hotel, Rochester, N. Y., has been modified from the setup given on page 262 of the Oct. 1946 issue as follows:

Monday Nov. 11, 2:00 p.m. session, add Measurement Methods for Ferromagnetic Materials, by H. W. Lamson of General Radio Co., and remove this paper from the last Wednesday session.

Tuesday Nov. 12, 9:30 a.m. session, Some New Tube Developments will be presented by F. E. Gehrke of Sylvania Laboratories instead of M. A. Acheson. An additional paper in this session is Wide Band I-F Amplifiers Above 150 MC, by M. T. Lebenbaum of Airborne Instruments Laboratory, Inc.

Wednesday Nov. 13, 9:30 a.m. session, add Application of Selenium Rectifiers to Receiver Designs, by H. Heins and T. M. Liimatainen of Sylvania Electric Products Inc. 2:00 p.m. session, add High Frequency A-M Broadcasting Designed for Small Community Use, by Sarkes Tarizan, A. Valdettaro, and M. Weijdel, consulting engineers. 8:00 p.m. photographic session—Recent Developments in Color Photography, by A. L. TerLouw of Eastman Kodak Co.

August Radio Output

A TOTAL OUTPUT of 1,442,757 radio sets was reported for August by RMA member-companies, and the corresponding Bureau of Census figure is 1,700,000 sets by the entire industry. RMA figures break down into 101,744 console and radio-phonograph combinations, 13,892 f-m sets, 1,030,183 table models of the electric type, and the rest battery and auto sets.

The latest OPA list of radio manufacturers includes names of 211 producers and 20 nonproducers of radio sets, along with 176 manufacturers and 10 nonmanufacturers

MICROPHONE NEWS

The NEW St. Louis OUTDOOR RUGGED

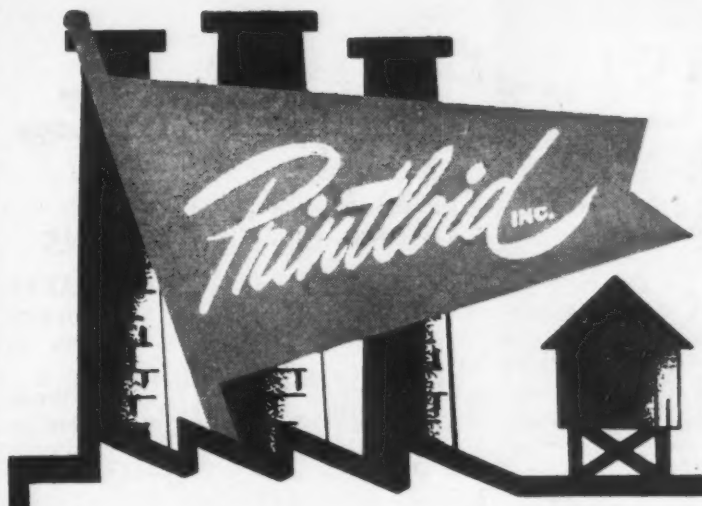
MICROPHONE

One of the "Finest Line of Modern Dynamic Microphones." Each engineered to fit your specific applications. Modern design—Rugged construction. Ranges: 40 to 9000 Cycles. Built to take the toughest treatment under the worst operating and climatic conditions. Alnico-V Magnet. Variable impedance output adjustable to low, 200, 500 or high. Gunmetal Gray, Black Lacquer or Olive Drab Finishes.

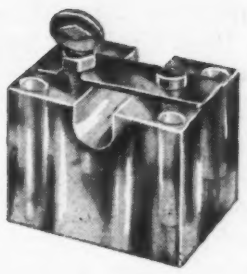
Write today for further information on the Complete St. Louis Line.

Licensed under patents of the American Tel. & Tel. Co. and Western Electric Company, Inc.

ST. LOUIS MICROPHONE CO.
2726-28 Brentwood Blvd.
St. Louis 17, Missouri



Complete plastic fabrication "ALL UNDER ONE ROOF"



Measuring 1¾" x 2½" x 1⅞", this acrylic stand-off insulator holds vertical whip antennas erect in marine radio installations. A brass strip with wing nut swings open to permit easy removal for low-bridge underpassing. This is another typical example of Printloid's ingenuity with plastics.

Write for our new 1946 catalog of special plastic fabrications.

"The House That Plastic Built"

Printloid INC.
PLASTIC FABRICATION
DEPT. E
93 MERCER STREET, NEW YORK 12, N. Y.

HEYCO SOLDERING LUGS
Available in various sizes and shapes. These copper lugs are easy to apply. Samples free.

HEYCO STRAIN RELIEFS
Three low-cost types. Prolong appliance life... Improve product performance... Act as grommet. Samples and literature.

HEYMAN MANUFACTURING CO.
510 Michigan Ave. Kenilworth, N. J.

HEYCO

VOLTMETERS FOR EVERY RF NEED...

Permanent accuracy, high stability and impedance input! You get all three with each of these three voltmeters. Suitable for laboratory, test bench or production line! Each has a frequency and voltage range adaptable to your particular needs . . . sturdy construction; easy-to-read meter scales!

STANDARD ELECTRONIC VOLTMETER MODEL VM-27A

RANGE: 0.1 to 100 volts in five ranges a-c and d-c. (1, 3, 10 and 100 volts full scale.)
ACCURACY: 2 percent of full scale on all ranges, on sinusoidal voltages.
CALIBRATION: Calibrated to read 0.707 of peak on a-c voltage, hence r.m.s. of a sinusoidal wave.
FREQUENCY RANGE: 2 cycles to over 100 megacycles with full accuracy from 50 cycles to 50 megacycles.
INPUT IMPEDANCE: d-c input 7 megohms, a-c input 4 megohms at audio frequencies and at radio frequencies equivalent to a capacity of 5 micro-microfarads having a power factor of 0.5 percent.
POWER SUPPLY: 105 to 125 volts 50-60 cycles at 30 watts.
TUBES: one 6H6 in probe, two matched 6J5GT and one 6X5GT rectifier.
DIMENSIONS: 8x8x8, probe 2 inches diameter, by 4 inches long.
WEIGHT: 11 lbs. less probe.
PRICE: $150.00 net, F.O.B. Flushing, N. Y.

MODEL VM-27-ZC
Same as Model VM-27A, but with means for setting meter to mid-scale on d-c.
PRICE: $155.00 net, F.O.B. Flushing, N. Y.

WRITE FOR DESCRIPTIVE BULLETINS

HIGH FREQUENCY ELECTRONIC VOLTMETER MODEL 32

RANGE: 0.3 to 300 volts r-f in five ranges (3, 10, 30, 100 and 300 volts full scale).
ACCURACY: 5 per cent of full scale on all ranges, on sinusoidal voltages.
FREQUENCY RANGE: 500 kilocycles to 500 megacycles.
INPUT IMPEDANCE: 0.5 to 1 micro-microfarad at a Q of about 200.
POWER SUPPLY: 115 volts 60 cycles at 30 watts.
TUBES: One 6AL5 in probe, two matched 6J5GT and one 6X5GT rectifier.
DIMENSIONS: 5⅛x9⅛x9⅛.
WEIGHT: 8 lbs.
PRICE: $99.50 F.O.B. Flushing, N. Y. (net)

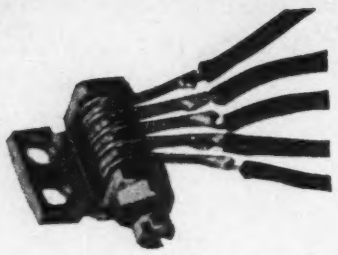
HIGH VOLTAGE ELECTRONIC VOLTMETER MODEL 31

RANGE: 10 to 10,000 volts r-f in five ranges (100, 300, 1000, 3000 and 10,000 volts full scale).
ACCURACY: 5 percent of full scale on all ranges, on sinusoidal voltages.
FREQUENCY RANGE: 100 kilocycles to 100 megacycles.
INPUT IMPEDANCE: Approximately 1 micro-microfarad at a Q of over 500.
POWER SUPPLY: 115 volts 60 cycles at 30 watts.
TUBES: One 6AL5 in probe, two matched 6J5GT and one 6X5GT rectifier.
DIMENSIONS: 5⅛x9⅛x9⅛.
WEIGHT: 8 lbs.
PRICE: $99.50 net, F.O.B. Flushing, N. Y.

ALFRED W. BARBER LABORATORIES ★ 34-06 FRANCIS LEWIS BLVD. FLUSHING • NEW YORK

BRADLEY

COPPER OXIDE RECTIFIERS



now . . .

a "universal" replacement rectifier

One rectifier for all circuits with A.C. voltages and D.C. currents within the unit's rating — that is Bradley's new "Coprox" Model CX2E4U.

Pre-soldered leads to prevent overheating during assembly and other Bradley features are embodied in this useful model, which offers 3 rating ranges as a half-wave, 2 as a double half-wave, 2 as a full back-to-back, and one as a full wave bridge.

Write for the CX2E4U Circuit Sheet for complete data.

Illustrated literature, available on request, shows more models of copper oxide rectifiers, plus a line of selenium rectifiers and photocells. Write for "The Bradley Line."

BRADLEY LABORATORIES, INC.

82 Meadow St. New Haven 10, Conn.

of phonographs. OPA officials believe that many newcomers dropped out upon receiving unsatisfactory price ceilings or have stopped producing as well-known brands became plentiful.

Live Pickup Demonstrated with UHF Color Television

SUCCESSFUL DEMONSTRATION of color television for live pickups has been announced, using a studio-type orthicon. Images were viewed in a fully lighted room. Color breakup in fast sports scenes such as boxing was not discernible, according to the CBS press release. Remote live pickup color equipment for both outdoor and indoor events is scheduled for operation by the end of the year. A new aluminum-backed cathode-ray receiving tube that concentrates the light on the viewing screen was used in the receivers.

Radio for Private Fliers

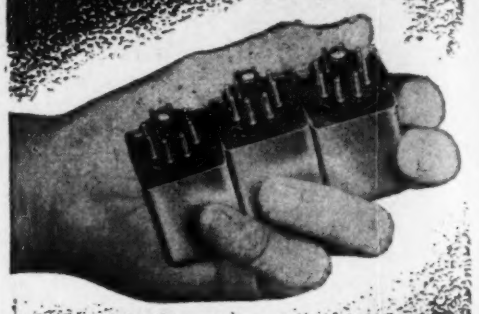
TWO NEW FREQUENCIES to be used by private aircraft will be guarded by the Civil Aeronautics Administration beginning Jan. 1, 1947. These are 121.1 mc for air to ground communication, and 122.5 mc for air to ground communication at airport control towers. The present frequencies 131.7 and 131.9 mc for these purposes will continue to be guarded. It is expected that some time may elapse before all municipal and private airports acquire the necessary vhf equipment to match this CAA service for private fliers.

MEETINGS TO COME

NOV. 11-13; ROCHESTER FALL MEETING; Sheraton Hotel, Rochester, N. Y.; technical papers and exhibits.

NOV. 11-14; INTERNATIONAL MUNICIPAL SIGNAL ASSOCIATION; Annual Meeting; Miami, Florida; technical program and exhibits

So little...



YET SO EFFECTIVE

Plug-In Sensitive Relays-- More Compact Than Ever Before

SIGMA Type 41 RO (DC); 41 ROZ (AC)

NEW FEATURES OF THIS DESIGN:

- Fits octal socket.
- Outline dimensions: 1¼" x 1¼" x 2" above socket.

  Permits lining up contiguous relays as close together as the smallest octal sockets will permit.

Features of All SIGMA Series 41 Relays:

- DC sensitivity: — 0.020 watts (min. input.)
- AC sensitivity: — 0.1 volt-ampere (min. input.)

  One standard 110 volt AC model draws about 1.5 milliampere.
- Contact ratings up to 15 amperes on low voltage.
- High quality construction — mechanically rugged.
- Very low cost.

SIGMA sales and engineering departments are ready to give your relay problems prompt analysis and action.

SIGMA

Sigma Instruments, INC.

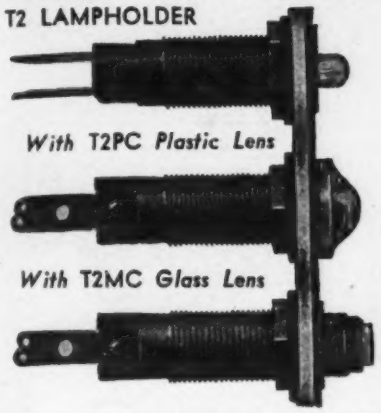
Sensitive RELAYS

62 Ceylon St., Boston 21, Mass.

KIRKLAND Pioneer
INDICATING LAMPS

TYPE T2 UNITS

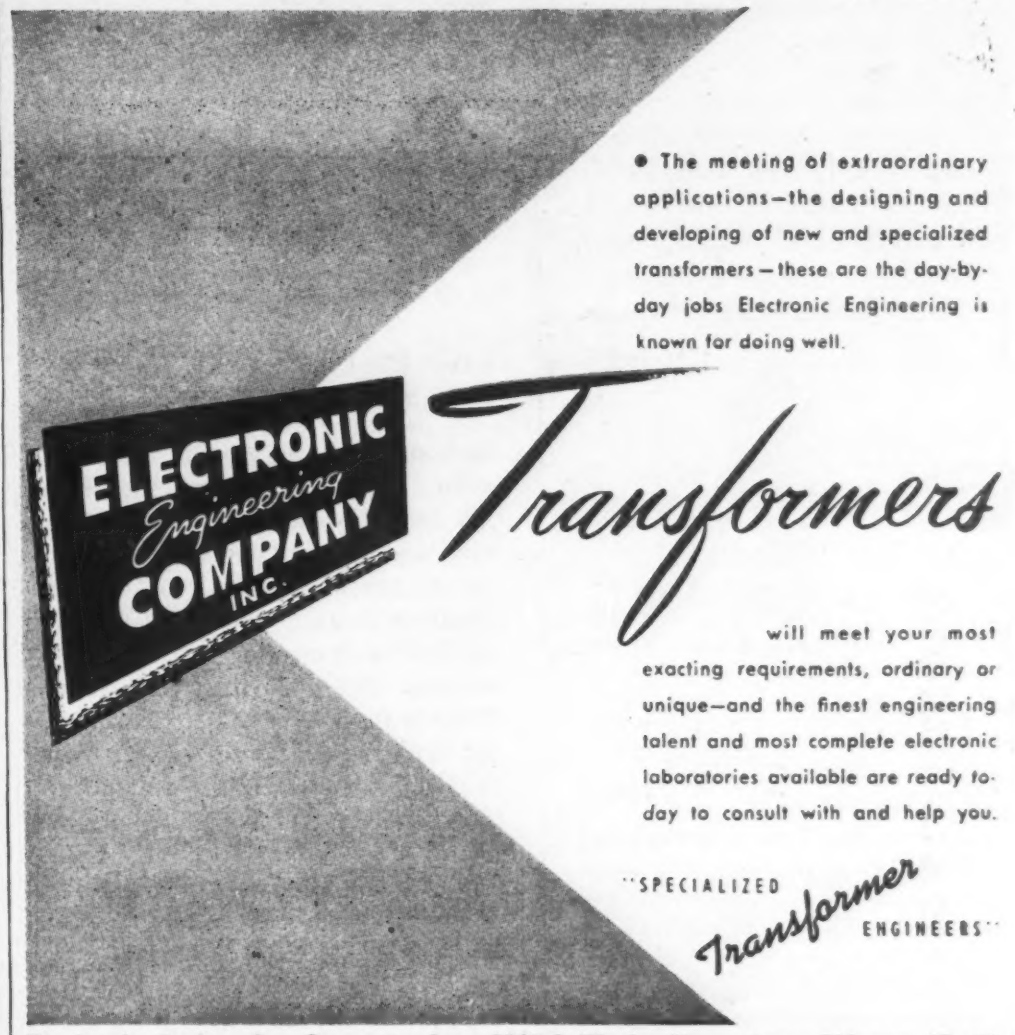
T2 LAMPHOLDER



T2 lampholder, molded of bakelite, holding lip, dia. 11/16". Tip of lamp bulb protrudes sufficiently to be removed from front of panel without use of special tool.
Very low current consumption bulb (0.038 max. amp. on 24 volts). Series resistor of small size on 120-220-440 volts, etc.
T2PC Lens-cap, molded in plastic.
T2MC Lens-cap, metal with glass lens.

WRITE TODAY FOR CATALOGUE

THE H. R. KIRKLAND COMPANY
8 King Street Morristown, N. J.



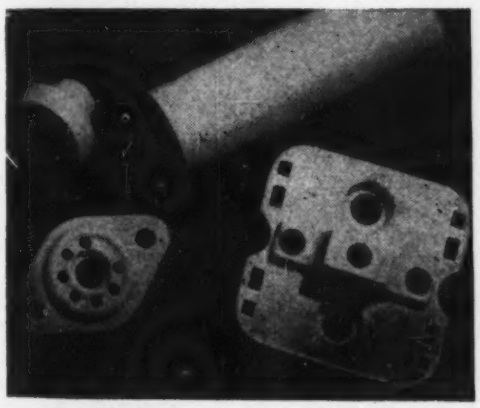
• The meeting of extraordinary applications—the designing and developing of new and specialized transformers—these are the day-by-day jobs Electronic Engineering is known for doing well.

Transformers

will meet your most exacting requirements, ordinary or unique—and the finest engineering talent and most complete electronic laboratories available are ready today to consult with and help you.

"SPECIALIZED *Transformer* ENGINEERS"

Electronic Engineering Company, Inc., 3223-9 W. Armitage Ave., Chicago 47, Ill.



Lavite STEATITE CERAMIC

Properties and Characteristics of Our LAVITE S1-5 Steatite Ceramic Body

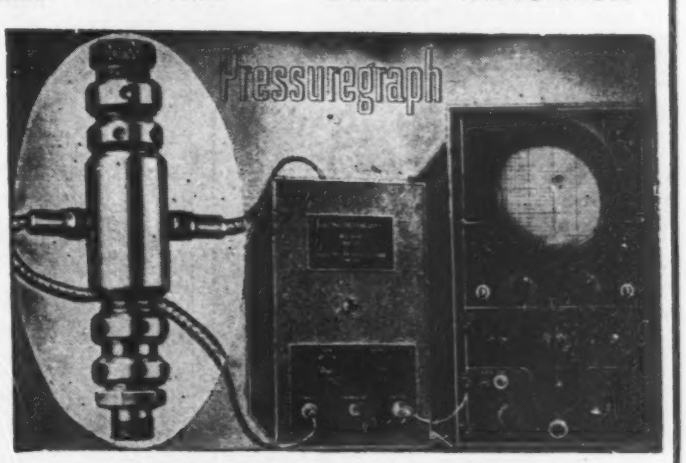
Compressive Strength	96,000 lbs. per square inch
Tensile Strength	7,200 lbs. per square inch
Flexural Strength	10,500 lbs. per square inch
Modulus of Rupture	20,000 lbs. per square inch
Dielectric Strength	235 volts per mil
Dielectric Constant	6.42 (Frequency of 1 megacycle)
Loss Factor	2.90 (Frequency of 1 megacycle)
Power Factor	.446 (Frequency of 1 megacycle)
Bulk Specific Gravity	2.664%
Density (from above gravity)	0.096 lbs. per cubic inch
Hardness (Mohr scale)	7.0
Softening Temperature	2,350° F.
Linear Coefficient of Expansion	8.13x10—6
Moisture Absorption (ASTM D-116-42-A)	0.009%

Design engineers and manufacturers in the radio, electrical and electronic fields are finding in LAVITE the precise qualities called for in their specifications . . . high compressive and dielectric strength, low moisture absorption and resistance to rot, fumes, acids, and high heat. The exceedingly low loss-factor of LAVITE plus its excellent workability makes it ideal for all high frequency applications.

We will gladly supply samples for testing.

D. M. STEWARD MFG. COMPANY
Main Office & Works Chattanooga, Tenn.
Needham, Mass. Chicago Los Angeles

New! PRESSUREGRAPH
LINEAR PRESSURE — TIME — CURVE INDICATOR



Indicates in linear response, on screen of cathode ray oscillograph, the pressure - time - curve of any internal combustion engine, pump, airline, or other pressure system where pressure measurements are desired. Covers wide range of engine speeds and pressures up to 10,000 p.s.i. Screws into cylinder and can be calibrated using static pressures. Vibration-proof. Accurate, dependable for frequent engine tuning. Simple operation — only one control.

Also Pioneer Manufacturers of

THE FAMOUS *Electro* BATTERY ELIMINATORS

A complete line — Models for use anywhere beyond high line connections (operate from 6 volt battery) — Others for operation from 110 volt AC. Improve radio reception. Greatly reduce battery drain.

For complete information write

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549 W. Randolph St., Chicago 6, Ill. Phone STate 7444

An entirely new vista in circuit conception and development now possible with Victoreen sub-miniature electrometer vacuum tubes.

Actual Size

Consider these factors for research . . . laboratory . . . production:

1. Low filament drain 10 milliamperes.
2. High input resistance 10^{16} ohms.
3. Versatility in instrumentation for chemical, oil, nuclear physics research, etc.
4. Ideal for electrometer applications.
5. Extreme portability—low battery drain.

Available As

DIODES
TRIODES
TETRODES
PENTODES

Actual size

Victoreen hi-megohm resistors are specially designed for the hard applications where stability with long life is required. Designed for laboratory use and fine instrumentation. Vacuum sealed in glass to cover a range of 100 to 10,000,000 megohms.

Write for technical data booklet on tubes and resistors.

THE VICTOREEN INSTRUMENT CO.
3800 PERKINS AVENUE
CLEVELAND 14, OHIO

cover fire and police radio, signaling, etc.

NOV. 19-21; COMMUNICATIONS SECTION, ASSOCIATION OF AMERICAN RAILROADS; Annual Session; Hotel Statler, Detroit, Mich.; four papers on communications subjects.

NOV. 18-22; THE NATIONAL METAL EXPOSITION; Municipal Auditorium, Atlantic City, N. J.; held in conjunction with annual meetings of The American Industrial Radium and X-ray Society, The American Welding Society, The American Society for Metals, and two sections of the American Institute of Mining and Metallurgical Engineers. Of more than 70 technical papers to be delivered at ASM meetings, one each day in the afternoon will be devoted to Electronic Methods of Inspection of Metals.

DEC. 2-7; NATIONAL POWER SHOW Grand Central Palace, New York City.

DEC. 5-7; JOINT EMSA AND ASXRED WINTER MEETING; Mellon Institute of Industrial Research and Univ. of Pittsburgh, Pittsburgh, Pa.; sponsored by Electron Microscope Society of America and American Society for X-ray and Electron Diffraction; make dinner reservations with Dr. Max Lauffer, Univ. of Pittsburgh.

JAN. 23-26; SOCIETY OF THE PLASTICS INDUSTRY; technical papers and exhibit; Edgewater Beach Hotel, Chicago.

JAN. 27-31; ELECTRICAL ENGINEERING EXPOSITION; held concurrently with AIEE winter convention; 71st Regiment Armory, New York City.

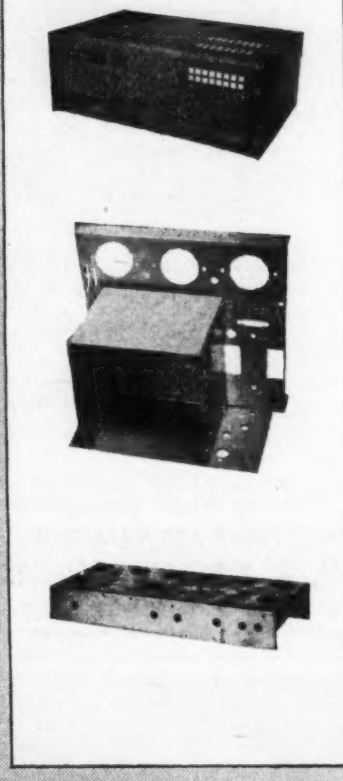
JAN. 27-31; INTERNATIONAL HEATING AND VENTILATING EXPOSITION; Lakeside Hall, Cleveland, Ohio.

BUSINESS NEWS

BENDIX AVIATION CORP. has been for many months engaged in research on controls and engine accessories for guided missiles and pilotless aircraft, with Dr. Harner Selvidge, formerly of Johns Hopkins University, as director. Two laboratories are devoted exclusively

AT YOUR SERVICE

TO HELP YOU WITH YOUR SHEET METAL FABRICATION REQUIREMENTS.



SHEET METAL PRODUCTS — such as:
INSTRUMENT PANELS, RADIO COMMUNICATION CASES and ENCLOSURES, OSCILLATOR BOXES, CHASSIS and CABINET ASSEMBLIES RACKS and SPARE PARTS BOXES, WATERPROOF CABINETS and BOXES, METAL STAMPINGS, FORMING and WELDING of FERROUS and NONFERROUS METALS.

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RADIONIC EQUIPMENT CO.
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Please send me a FREE copy of your 1947 Catalog. I understand it has thousands of items illustrated, described and priced and will be a great help to me in my search for "hard-to-find" radio equipment.

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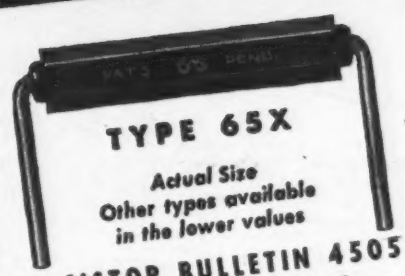
MOLDED S·S White RESISTORS

The "All-Weather" Resistors



Actual Size
Other types available in the lower values

RESISTOR BULLETIN 4505 GIVES FULL DETAILS . . .

It shows illustrations of the different types of S. S. White Molded Resistors and gives details about construction, dimensions, etc. A copy, with Price List will be mailed on request. Write for it—today.

- Noiseless in operation
- Strong and durable
- Good performance in all climates

STANDARD RANGE
1000 ohms to 10 megohms

• NOISE TESTED •

At slight additional cost, resistors in the Standard Range are supplied with each resistor noise tested to the following standard: "For the complete audio frequency range, resistor shall have less noise than corresponds to a change of resistance of 1 part in 1,000,000."

HIGH VALUES
15 to 1,000,000 megohms

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THE S. S. WHITE DENTAL MFG. CO.
DEPT. R, 10 EAST 40th ST., NEW YORK 16, N. Y.

FLEXIBLE SHAFTS • FLEXIBLE SHAFT TOOLS • AIRCRAFT ACCESSORIES
SMALL CUTTING AND GRINDING TOOLS • SPECIAL FORMULA RUBBERS
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Established in 1935

Electrical Coils and Transformers

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NO. 1 OF A SERIES

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The power is there—when you go on the air!

Full Power in 3/10ths of a second

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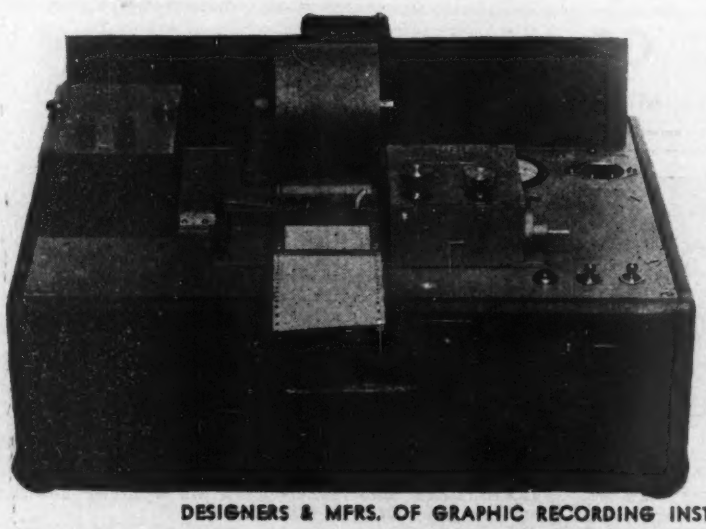
A unique, versatile instrument for the acoustical engineer. Interchangeable input potentiometers in various ranges (log. DB, linear, phon).



MODEL PL

- Reverberation Time
- Decay of Sound
- Sound Intensities
- Loudness

Write for technical data

DESIGNERS & MFRS. OF GRAPHIC RECORDING INSTRUMENTS

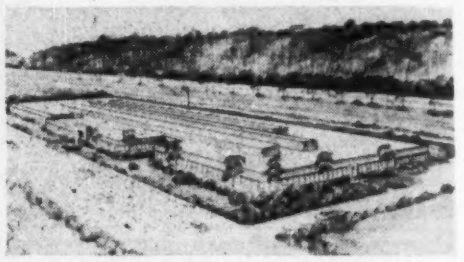
SOUND APPARATUS CO.
233 BROADWAY • NEW YORK 7, N Y

to this work, one at the Eclipse-Pioneer division in Teterboro, N. J. with R. Beardsley Graham as chief engineer, and the other at the Pacific division in North Hollywood, California with Rollin M. Russell as executive engineer.

NORTH AMERICAN PHILIPS CO., INC. has moved its Wire Division from Dobbs Ferry, N. Y. to Lewiston, Maine. A new addition has been erected to house the added production operations there.

A. W. FRANKLIN MFG. CORP. has relocated in a modern new building at 43-20 34th St., Long Island City, N. Y.

THE INDIANA STEEL PRODUCTS CO. has acquired approximately 14 acres of land along the Saw Mill River Parkway in Greenburgh, New York



Artist's sketch of new magnet plant

as a site for their proposed new and ultramodern plant to be used largely for production of special products in the permanent magnet field.

SENTINEL LABORATORIES, Philadelphia, Pa., has opened an electronics engineering service for research, design, and development.

STERLING ELECTRONIC CO., Pasadena, Calif., has been formed recently with J. S. Jackson, Jr., as president, and production of electronic volt-ohmmeters is under way.

FARNSWORTH TELEVISION & RADIO CORP., Fort Wayne, Ind., demonstrated a complete vhf railroad radio communications system at Potomac Yard, Washington, D. C. Sept. 11 for railroad, government, military, civic, press, and radio representatives.

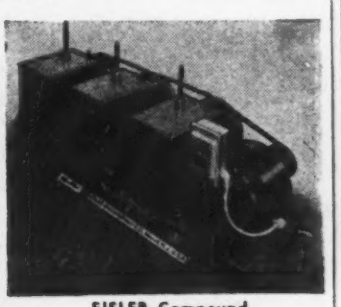
MCGRAW-HILL BOOK CO., INC., New York, N. Y. announces a change of policy whereby catalog descriptions of their books will contain the year of publication or last revision. Prices on approximately 90 percent

EISLER EQUIPMENT*

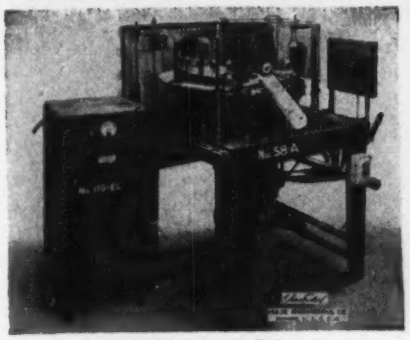
...COMPLETE AND DIVERSIFIED FOR EVERY PHASE OF ELECTRONIC MANUFACTURE!

TRANSFORMERS of all types — furnace, distribution, power, phase changing, air, oil, induction, water cooled, plate, filament and auto-transformers. Filter chokes and inter-phase reactors.

Transformers supplied from ¼ to 300 KVA.



EISLER Compound Vacuum Pump.



24 Head Radio Tube Exhausting Machine.

EISLER Spotwelders from ¼ to 250 KVA.

*EISLER machines are in use and in production by 99% of all American radio tube and incandescent lamp manufacturers and throughou: the world.

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For Originality LOOK TO XCELITE

XCELITE screwdrivers give you a lifetime of efficient use. Their SAE 6150 Chrome Vanadium steel shafts are firmly anchored in tough, genuine XCELITE handles that fit your grip perfectly, XCELITE blades, ground lengthwise with the flat belt, won't slip off the screw slot easily. Keep asking your dealer for XCELITE . . . you'll soon see them in quantity!

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Quality Tools **PREFERRED BY EXPERTS**

To some men "radio" is a magic word. It piques their curiosity—fires their imagination—spurs them to action! Their every thought is devoted to mastering the complex mechanisms by which radio is controlled.

Experience has proved that such men, with radio in their blood, make the finest technicians. As they say, in measuring top talent radio programs, these men have a high "Hooper"—they're tops!

It has been our good fortune to attract as students and to develop thousands of such men from "hams" into well qualified technicians in broadcasting, communications, sound, manufacturing, sales and service.

Yes, since the inception of radio we have helped direct the destinies of thousands of aspiring men seeking an outlet for their talents. During the past four decades we have acquired an interesting insight into the motives which inspire mechanically minded men to *apply* their skill and training to assure maximum efficiency on the job.

For this reason we believe we can be of service to you in your personnel problem—as it applies to your technical staff.

We think you'll be interested in our observations, as they apply to YOUR personnel problems. We feel certain you'll want to clip the coupon below and send for our free booklet "*Report to Industry.*" Whether you employ one man or hundreds, you will enjoy this factual, informative presentation. Send for it today! No obligation.

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"I am employed as a radio mechanic at the Signal Corps Laboratories at Fort Monmouth. In my work I have many times used Kwikheat Soldering Irons. I had never seen, nor heard of your irons until I came here, but I am certainly convinced that *they are the best irons that can be obtained.* They (Kwikheats) are a real pleasure to work with."

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Check These Many KWIKHEAT Features...

- Thermostatic Control
- Heats in 90 seconds
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- Six interchangeable tips
- Tips need less dressing
- Power cost reduced

225-Watt List $11.00
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SIX TIP STYLES

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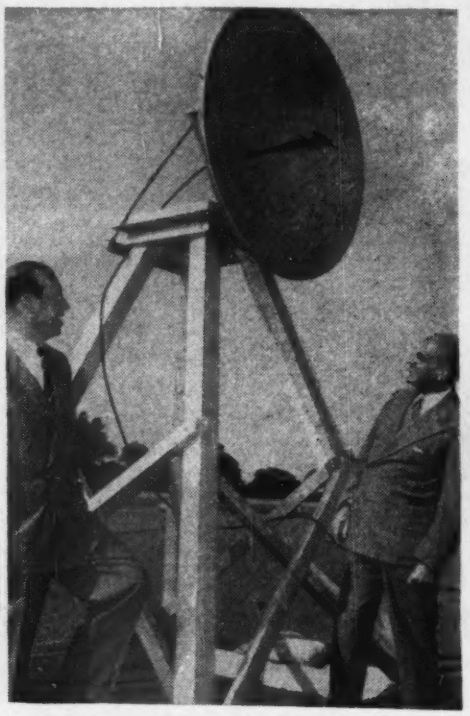
A Division of
Sound Equipment Coporation of California
3903 San Fernando Rd., Glendale 4, Calif.

of their books were raised as of July 1, 1946 to meet increased costs.

FEDERAL TELECOMMUNICATION LABORATORIES, Nutley, N. J., demonstrated to the press Sept. 9 an adaption of I.T.&T.'s pulse time modulation system whereby eight



Parabolic antenna used in eight-channel ptm demonstration, with Henri Busignies (left) and H. H. Buttner, director and president respectively of Federal Telecommunication Laboratories

separate radio broadcast programs can be placed on one carrier frequency and radiated over one antenna.

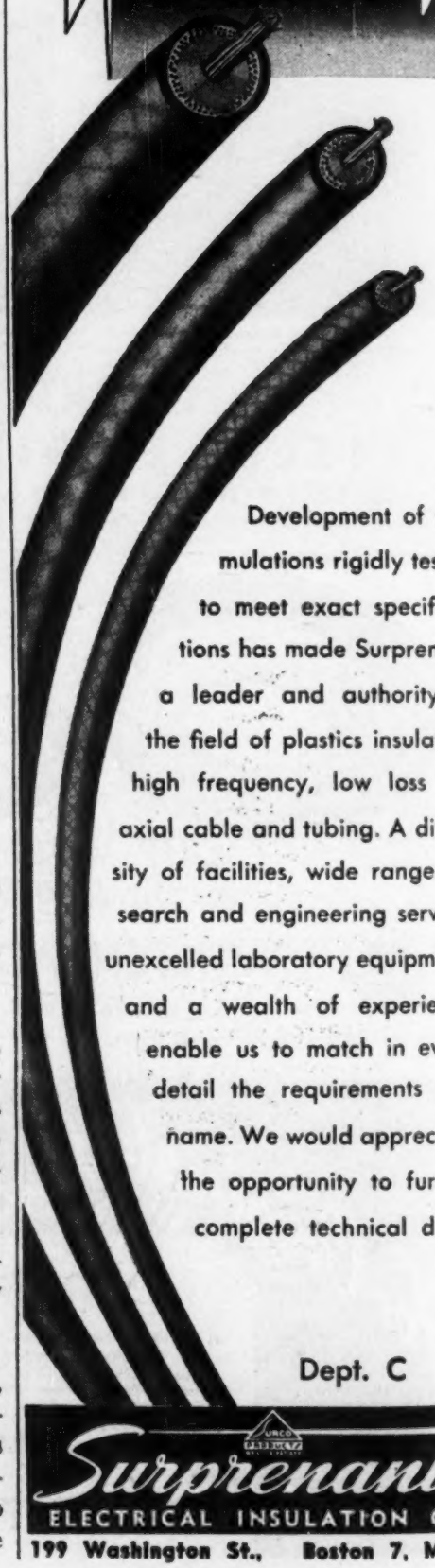
BARKER & WILLIAMSON, Upper Darby, Pa., have leased a new factory building in Bristol, Pa. for special and developmental work.

BENDIX RADIO DIVISION, Baltimore, Md. has been granted an experimental license by the FCC for a full-color television broadcasting station, to be located in their Towson, Md. plant.

WORNER ELECTRONIC DEVICES, Chicago, is moving into its own new plant in Rankin, Illinois.

PHILCO CORPORATION, Philadelphia, has started production of radiophonograph combinations in its new $2,250,000 plant in Philadelphia, adjoining the main Philco plants. When in full operation, the

CUSTOM MADE
COAXIAL CABLE and TUBING



Development of formulations rigidly tested to meet exact specifications has made Surprenant a leader and authority in the field of plastics insulated, high frequency, low loss coaxial cable and tubing. A diversity of facilities, wide range research and engineering service, unexcelled laboratory equipment, and a wealth of experience enable us to match in every detail the requirements you name. We would appreciate the opportunity to furnish complete technical data.

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There are many kinds for special uses, such as applications calling for resistance to electricity, heat, moisture, chemicals or weathering agents. There are more than a score of formulas in actual production at one time in our factory.

Send for "A Brief Survey of Technical Characteristics of Molded Ceramic Products." It is right to the point.

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The **STAR**
PORCELAIN CO.
Electronics Dept.
Trenton 9, N. J.

COUNT AND CONTROL FAST!

Potter
DUAL-PREDETERMINED ELECTRONIC COUNTER

A time and money-saving instrument

- **For processes requiring a rapidly repeated operation to occur after a predetermined number of counts!**
- **For counting and stacking sheet metal.**
- **For accurate control of length and spacing of slide fasteners.**
- **For use in automatic packaging of objects such as buttons and pills.**
- **And for many other operations throughout industry.**

This instrument uses three to four standard Potter 4-tube counter decade circuits arranged to give two independent predetermining channels in which any number, from 0 to 10,000, may be initially set up. Each channel is alternately pre-set to the desired predetermined number by automatic, self-contained circuits at a speed not obtainable with predetermined mechanical counters. The input is arranged for operation with either make-contacts or sharp negative pulses. Input frequencies may be in excess of 1000 cycles per second. The output includes an ultra-high speed relay with single pole double throw contacts. The standard unit may be ordered for a total count capacity of 1000 to 10,000 with either the single or dual predetermining channels. Other count capacities on special order. Write for additional details.

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POTENTIOMETERS
JACKS
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RESISTORS
PHONE PLUGS
SWITCHES
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WE don't guarantee that the NEW BUD METAL WALL TYPE SPEAKER CASE will stand up against a sledge hammer . . . but we do say that it is not subject to the cracking, splitting and warping that characterize ordinary wooden speaker cases.

This new metal wall type speaker case is not only superior in appearance and construction . . . but it has reproduction capabilities equal to the finest wood housings. Keyway holes are provided for wall mounting and there are four embossed feet on the bottom in case you require its use on a table or other surface. It is finished in a rich brown wrinkle. Your local distributor will be glad to show this BUD Speaker Cabinet to you!

BUD
Can Supply All Your Needs!

. . . with the latest types of equipment including: condensers—chokes — coils — insulators — plugs — jacks — switches — dials — test leads — jewel lights and a complete line of ultra-modern cabinets and chassis.

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CLEVELAND 3, OHIO

new plant will have continuous radio production lines claimed to be the longest in the world.

ELECTRO-VOICE has combined all facilities of its three South Bend

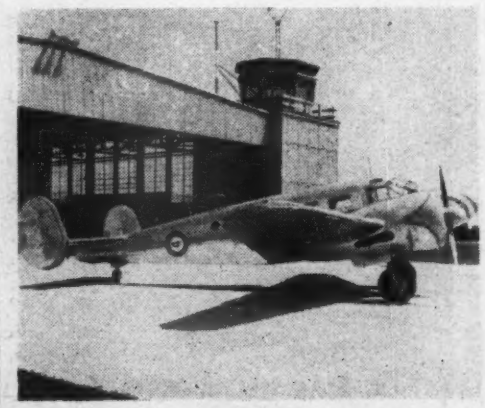
New Electro-Voice plant for manufacturing complete line of microphones

plants in one big modern plant 14 miles north in Buchanan, Michigan.

RADIO ENGINEERING LABORATORIES, INC., Long Island City, N. Y. has tentatively scheduled for Dec. 2, 3, and 4 an f-m engineering clinic to be headed by Frank A. Gunther, devoted to review of f-m theory and solution of problems facing f-m broadcast station engineers. REL engineers and outstanding engineers in the f-m field will participate.

RCA VICTOR DIVISION, Camden, N. J. has made initial deliveries of land and mobile f-m transmitters and receivers to the three Bell System companies that will provide two-way highway radiotelephone service on or in the vicinity of the Boston Post Road running between New York and Boston. Six 250-watt land transmitters will be used, operating in the 30-44 mc band.

COLLINS RADIO CO., Cedar Rapids, Iowa, maintains a technical staff at its private hangar on Cedar Rapids Municipal airport, for the purpose



Beechcraft on apron of Collins hangar after installation of Collins type 17H-2 multi-channel transmitter

A major advancement in the recording blank field . . .

10 Year
GUARANTEE

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"Black Seal"
ALUMINUM RECORDING BLANKS

. . . at no increase in price!

After prolonged research and experimentation, we have introduced technological improvements into "Black Seal" blanks that not only increase life span, but materially enhance the other finer characteristics of these blanks. And so positive are we of the worth of these perfected "Black Seals" that we're offering them to you on an unconditional ten-year guarantee basis.

You can't afford to be a recording isolationist . . .

"Black Seal" blanks will not rip up, disintegrate or powder after the first playing if kept in storage for any long period of time. You are in no danger of losing valuable recordings in what, up until now, you have considered your safe library of recording blanks. No matter how well you may be satisfied with your present blanks, you can't afford to be a recording isolationist. Try "Black Seals"—if, for any reason whatsoever, you aren't satisfied, return them at our expense.

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MODEL 2405

Volt · Ohm Milliammeter

25,000 OHMS PER VOLT D. C.

NEW ENGINEERING
NEW DESIGN • NEW RANGES
50 RANGES

Voltage:	5 D.C. 0-10-50-250-500-1000 at 25000 ohms per volt. 5 A.C. 0-10-50-250-500-1000 at 1000 ohms per volt.
Current:	4 A.C. 0-.5-1-5-10 amp. 6 D.C. 0-50 microamperes—0-1-10-50-250 milliamperes—0-10 amperes.
4 Resistance	0-4000-40,000 ohms—4-40 megohms
6 Decibel	-10 to +15, +29, +43, +49, +55
Output	Condenser in series with A.C. volt ranges

STANDARDS ARE SET BY TRIPLETT

SPECIFICATIONS

NEW "SQUARE LINE" metal case, attractive tan "hammered" baked-on enamel, brown trim.

■ PLUG-IN RECTIFIER — replacement in case of overloading is as simple as changing radio tube.

■ READABILITY—the most readable of all Volt-Ohm-Milliammeter scales—5.6 inches long at top arc.

Model 2400 is similar but has D. C. volts Ranges at 5000 ohms per volt.

Write for complete description

Triplett

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WIRE & RIBBON for VACUUM TUBE FILAMENTS & GRIDS

● Many sizes and alloys for a range of applications such as miniature tubes, hearing aid tubes, low-current-drain battery tubes, receiving tubes . . .

● Melted and worked to assure maximum uniformity and strength. WIRES drawn to .0004" diameter; RIBBON rolled to .0001" thickness . . .

● Wollaston Process Wire drawn as small as .000010"; made to your specifications for diameter and resistance.

SPECIAL ALLOYS made to meet individual requirements. Write for list of stock alloys.

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DESIGNED FOR PRECISION JOBS.

Meet requirements of the electronic field — QUADRIGA WASHERS, to your specifications. Prompt delivery of any quantity. Special flat, tension and spring, formed and drawn, cupped and finishing. Write for valuable catalog.

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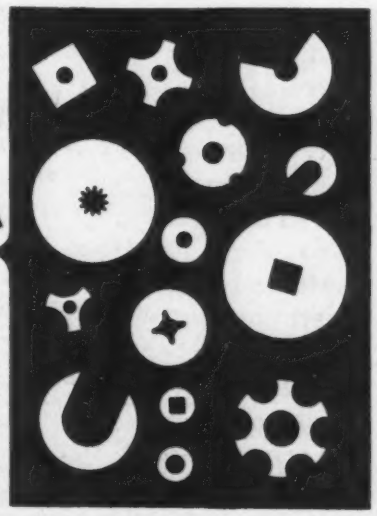

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● SCREW MACHINE PARTS
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Experienced fabrication and dependable service for all types of radio and electronic parts. Send us your drawings and specifications for quotation.
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Metal Work of Every Description

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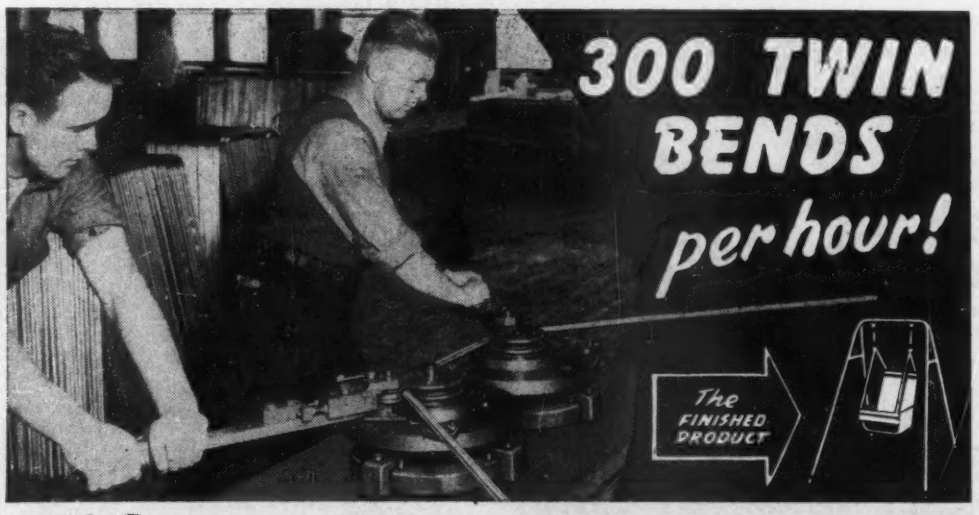
The new Gothard Indicator Light Assemblies Catalog is bigger and better than any similar catalog ever published. It offers a wealth of scientific data, which will greatly aid you in selecting the right assembly for your industrial, household appliance, radio or other applications. It also illustrates and describes the largest selection of Underwriters approved assemblies for any voltage and style of miniature lamps and built-in resistor assemblies for neon lamps. Here is the latest data published on Indicator Light Assemblies—ask for your copy immediately.

Gothard MANUFACTURING COMPANY
2114 CLEAR LAKE AVENUE, SPRINGFIELD, ILLINOIS
EXPORT DIVISION: 25 WARREN STREET • NEW YORK 7, N. Y.



With Two DI-ACRO BENDERS

A difficult production problem of forming two bends in a long length of tubing was solved by "teaming up" two DI-ACRO Benders as illustrated. This dual-forming arrangement saved installation of special machinery. Two accurately formed bends are obtained in one operation—without distortion of the tube and at a cost competitive to power operated equipment. More than 300 pieces are completed per hour—600 individual bends.

"DIE-LESS DUPLICATING" Often Does it Quicker WITHOUT DIES

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PERSONNEL

ARTHUR H. JONES, now with Gray Mfg. Co., Hartford, Conn., was awarded the Legion of Merit for his wartime services as Lieutenant Colonel in the Coast Artillery Corps, where he devised new and improved methods for radar spotting of mortars.

HENRY LAVIN, recently discharged from the Navy as chief radio technician, received an appointment as field engineer for Kahn and Co., Hartford, Conn.

L. MORGAN CRAFT has been elected vice-president in charge of engineering and manufacturing for The Collins Radio Co., Cedar Rapids, Iowa. Within a few years after joining the Collins organization in 1935 he was made chief engineer, and since then has assumed increasingly greater administrative responsibilities.

L. M. Craft

W. N. Tuttle

W. N. TUTTLE of General Radio Co. received the Medal of Freedom for distinguished work in adapting blind bombing equipment and technique for introduction into the Eighth Air Force.

EDWARD E. SCHULTZ, chief engineer of Press Wireless during the war,

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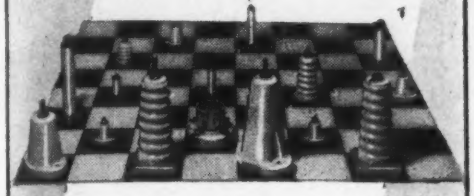

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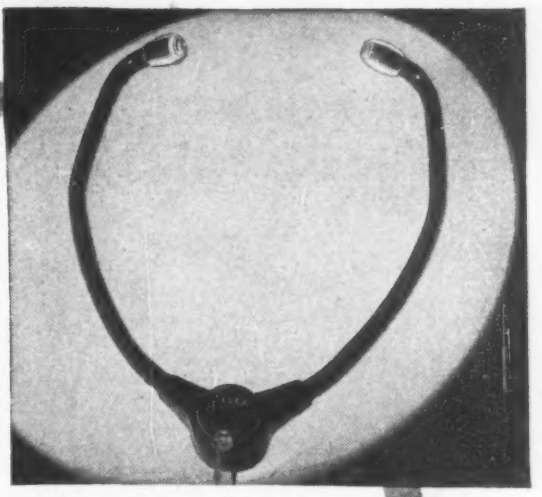

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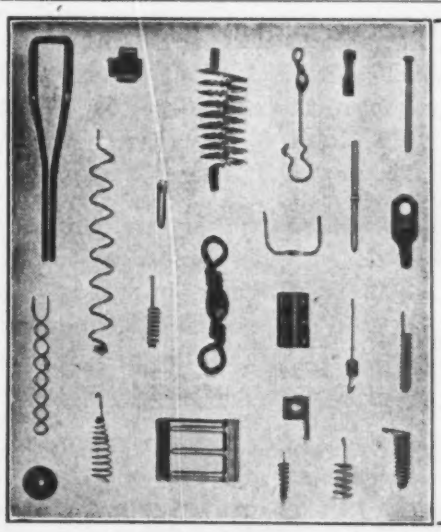

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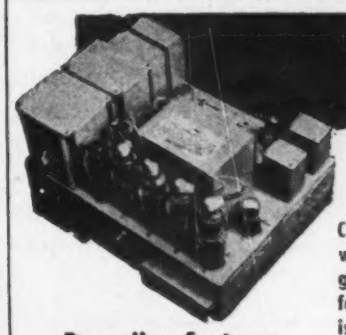

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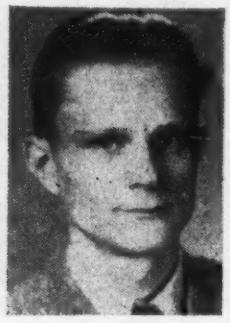
has joined Cook Electric Co., Chicago, and will assist in directing research on transient motion measuring instruments and electronic controls for aircraft.

ROY DALLY is now chief engineer in charge of phonograph needle and pickup design for Electrovox Co., Inc., Newark, N. J.

R. Dally



W. F. Frankart

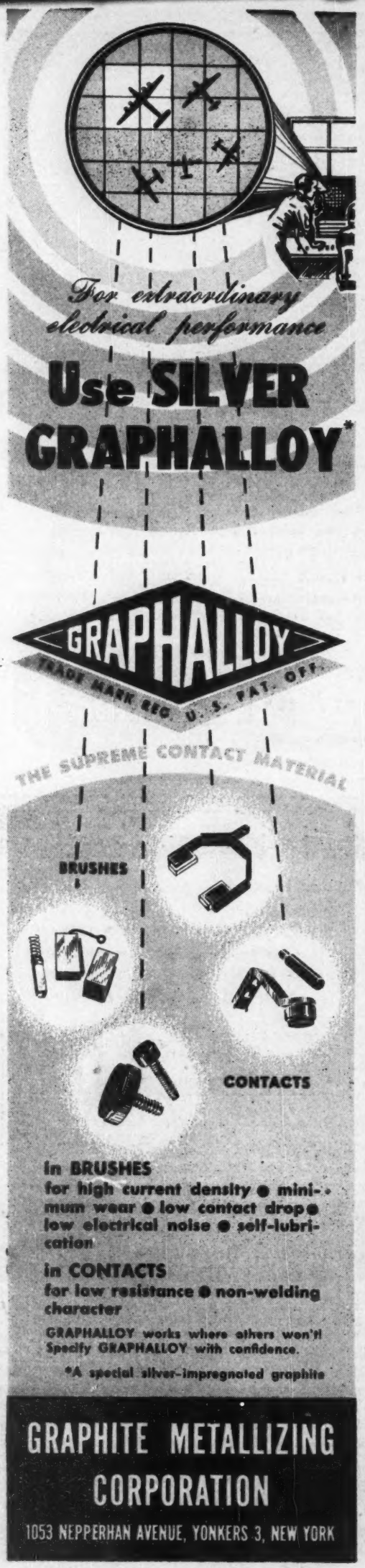
WILLIAM F. FRANKART has been appointed senior radio project engineer at Lear, Inc., Grand Rapids, Michigan. He was formerly chief radio engineer for Precision Specialties, Inc. of Los Angeles. Before that he was employed by Air Associates, Inc. of California as a design engineer, and previous to that was in turn assistant chief engineer at Aireon Mfg. Corp. of Kansas City and project engineer for Farnsworth Radio & Television Corp. of Fort Wayne, Indiana.

L. E. BESSEMER, formerly chief production engineer for Collins Radio Co., Cedar Rapids, Iowa, has been promoted to become general manager of the Manufacturing Division.

SAMUEL HEYMAN, formerly production manager of Aerovox Corp., becomes factory manager for the Tobe Deutschmann Corp., Canton, Mass.

ROBERT W. MCKIRDY, who served during the war as Electronics Liaison Officer between the Bureau of Ships and the British Admiralty Delegation, has joined Centro Research Laboratories, Inc., Briarcliff Manor, N. Y., as technical service director.

FIRST COMMERCIAL radio program was sponsored in 1922 by a Jackson Heights, N. Y. real estate company, Queensborough Corp. It paid $100 for ten minutes.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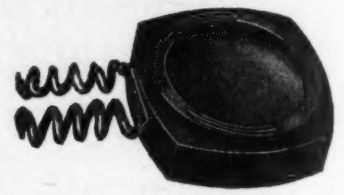

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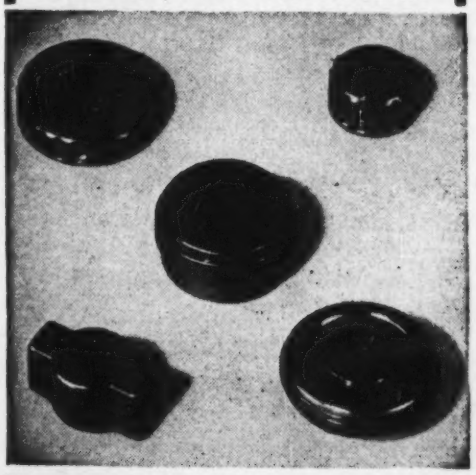

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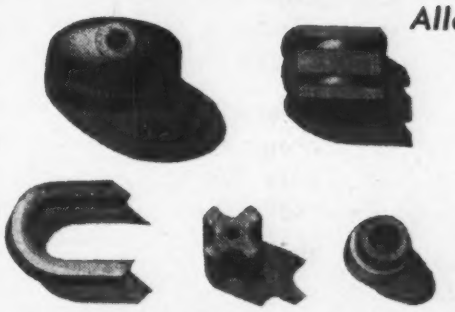

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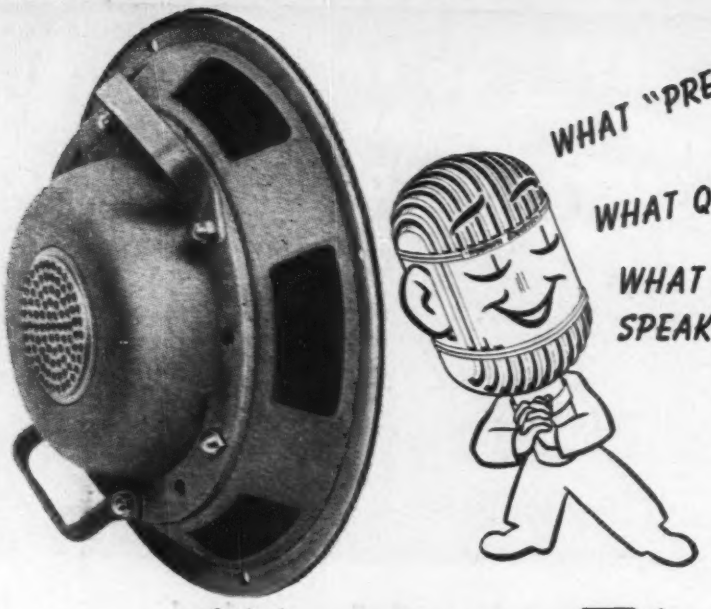

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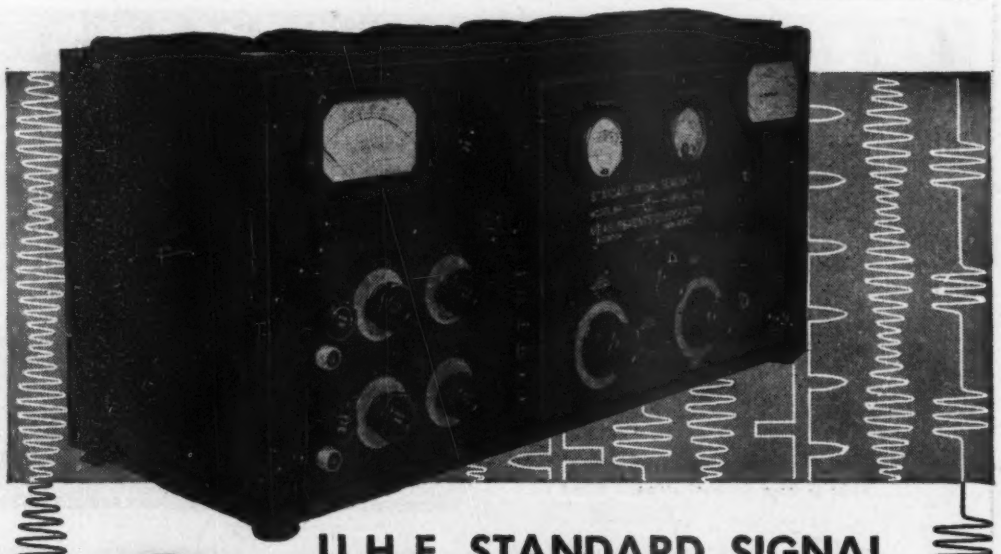

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Edited by Herbert J. Cooper, Head of Engineering Dept., South-West Essex Technical College, England. Chemical Publishing Co., Brooklyn 2, N. Y., 1946, 304 pages, $6.00.

ANY SINGLE volume that attempts to describe scientific instruments ranging from water meters and calculating machines through cathode-ray tubes and optical devices, must be arbitrary of choice. The editor has doubtless planned his volume for a given purpose, packing it with useful information, but the final result gives the feeling of perusing a mail-order catalog. Furthermore, though not labeled as such by the publisher, this is apparently a reprint of a British book, and illustrates British instruments.—A. A. MCK.

Radioman's Handbook

Compiled by technical staff of Coyne Electrical School. Published by Coyne Electrical School, Chicago, Ill., 355 pages, $3.25.

A CONGLOMERATION of elementary radio theory, examples of arithmetical calculations used in radio, and some of the simpler tables, charts, and nomographs used by technicians rather than engineers. The level of writing is for home radio students and radio shop technicians.—J. M.

Electron and Nuclear Counters

By SERGE A. KORFF, *Associate Professor of Physics, New York University. D. Van Nostrand Co., Inc., New York, N. Y., 212 pages, $3.00.*

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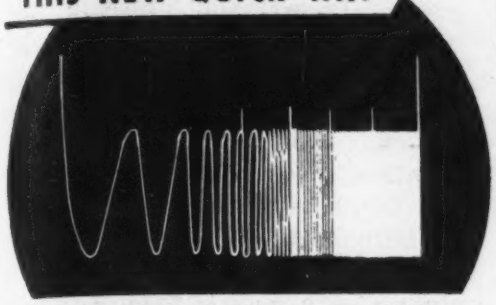

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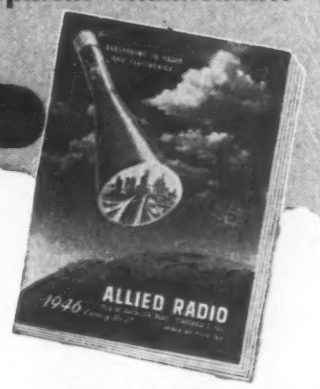

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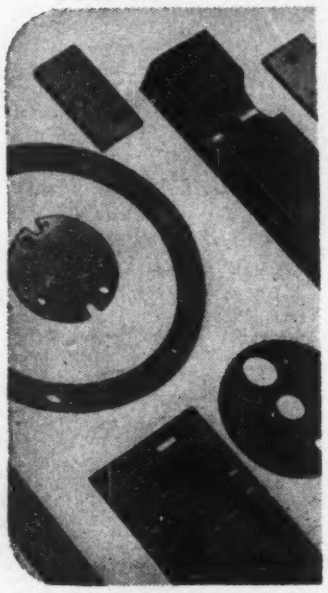

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changes in counter behavior as voltage is raised, and presents the terminology of counter circuits. Following chapters cover counting chambers, integrating types of ionization chambers, proportional counters, neutron counters, counters for heavy ionizing particles, nonselfquenching counters, and selfquenching counters. Chapter V gives highly practical suggestions for preparation and construction of counters, chapter VI covers errors and corrections in counting, and the final chapter covers auxiliary circuits such as quenching, coincidence, scaling, recording, voltage supply, regulating, integrating, and pulse amplifying circuits. Values of components for many of the circuits are given. A unique and valuable appendix contains a list of manufacturers of counters and associated equipment along with conventional reference and bibliography sections. All in all, this book constitutes a significant contribution to the literature of electronics.
—J. M.

Wave Propagation in Periodic Structures

By LEON BRILLOUIN, *Applied Mathematics Group at Columbia University. McGraw-Hill Book Co., Inc., New York,* 1946, 247 *pages,* $4.00.

MATHEMATICAL TREATMENTS of wave propagation in electric lines and filters, crystal lattices, and in an idealized elastic medium, being essentially identical, provide the theme of this short addition to the International Series in Pure and Applied Physics. For those who can make the mental jump from familiar electrical symbols to generalized notation and are not confused by the various particular physical phenomena to which the mathematics is applied, the work demonstrates how to use complex algebra and calculus in solving the problems under discussion. Wave propagation and boundary conditions of uniform systems are thoroughly analyzed. As the text was prepared from notes made by Mary H. Payne while attending the author's lectures, explanations that

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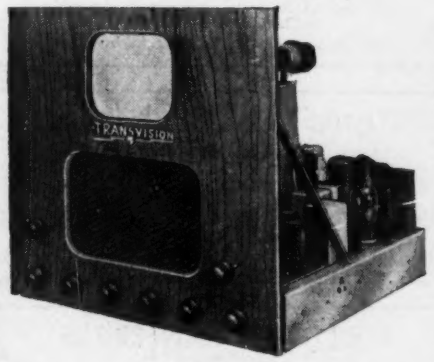

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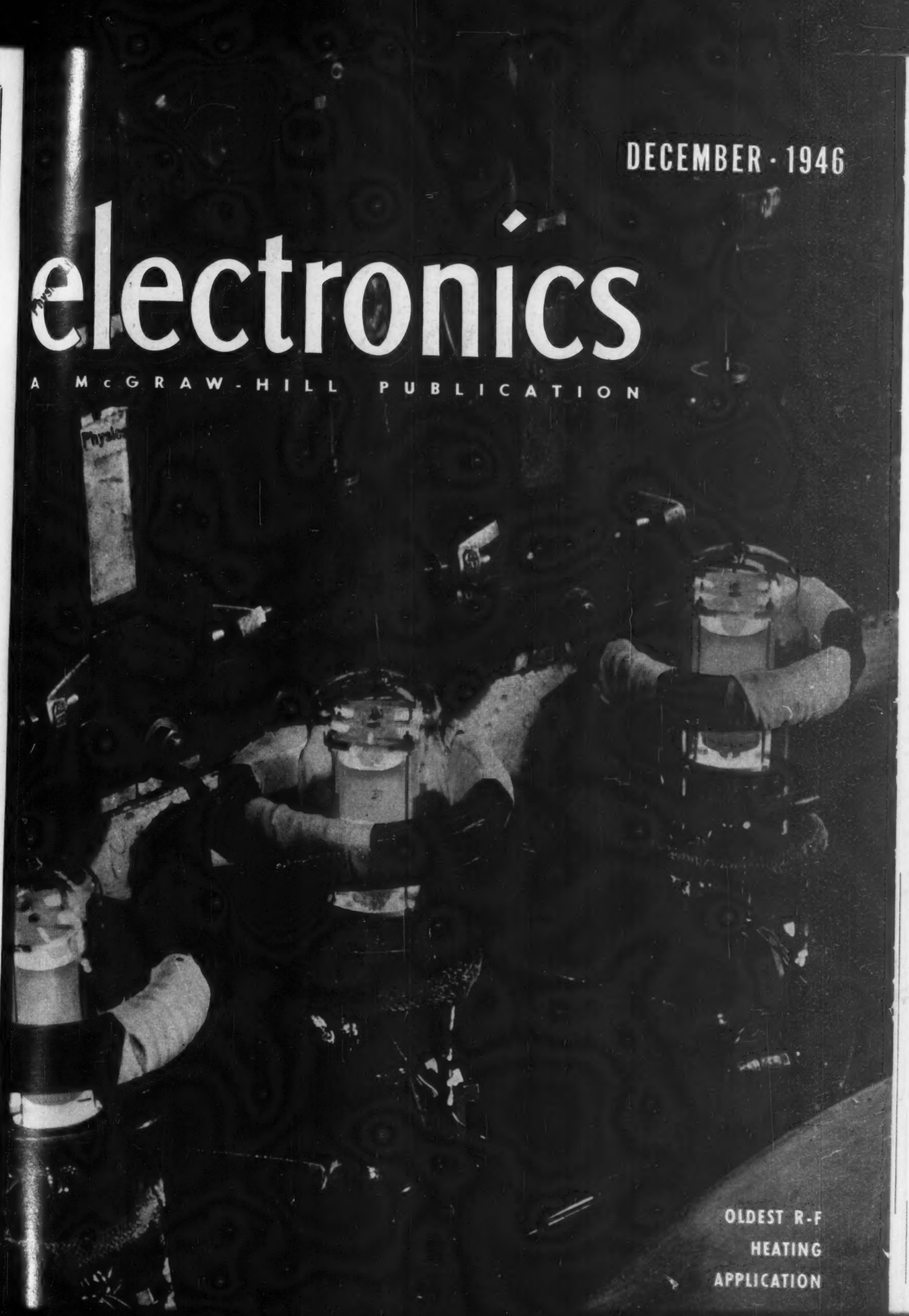

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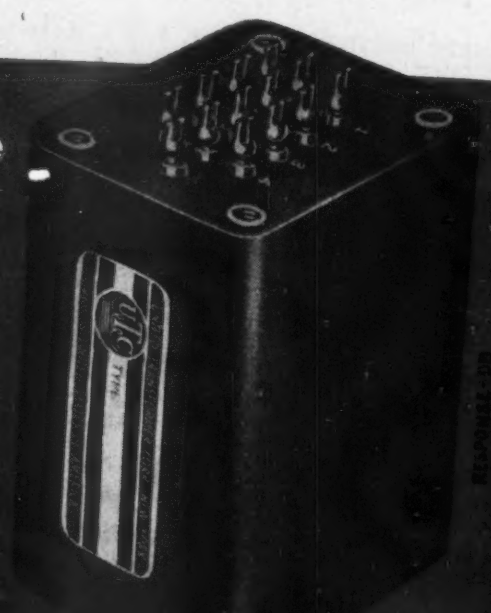

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